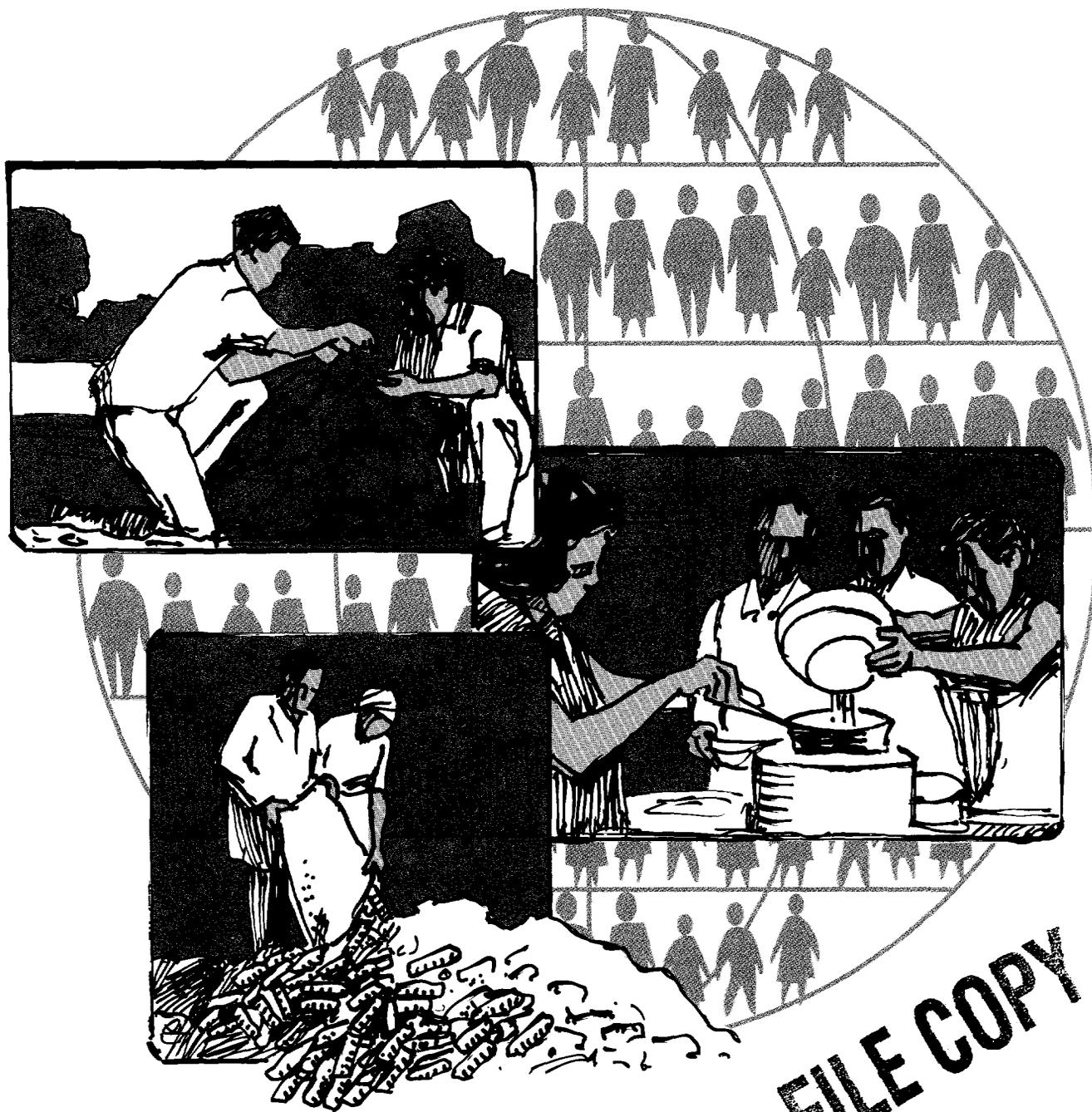




Agricultural Issues in the 1990s

Proceedings of the Eleventh Agriculture Sector Symposium

Lisa Garbus, Anthony Pritchard, and Odin Knudsen, editors



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**The World Bank
Washington, D.C.**

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Washington, D.C. 20433, U.S.A.

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First printing August 1991

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Library of Congress Cataloging-in-Publication Data

Agriculture Sector Symposium (11th : 1991 : World Bank)

Agricultural issues in the 1990s : proceedings of the Eleventh
Agriculture Sector Symposium / Lisa Garbus, Anthony Pritchard, and
Odin Knudsen, editors.

p. cm.

"Symposium held January 9-11, 1991"--Foreword.

Includes bibliographical references.

ISBN 0-8213-1890-X

1. Agriculture--Economic aspects--Congresses. 2. Agriculture and
state--Congresses. I. Garbus, Lisa, 1963- . II. Pritchard,
Anthony J., 1931- . III. Knudsen, Odin. IV. International Bank
for Reconstruction and Development. V. Title.

HD1405.A373 1991

336.1--dc20

91-24513

CIP

FOREWORD

These proceedings are the eleventh in a series of records of agricultural symposia presented at the World Bank since 1980. The theme of this year's symposium, held January 9-11, 1991, was "Agricultural Issues in the 1990s." Papers presented focused on technical development, the GATT negotiations, economic changes in Eastern Europe, and recent developments in agroindustry.

The symposium was opened by Barber Conable, president of the World Bank. Stating that "agriculture remains the main engine of growth" in the least developed countries, Mr. Conable stressed that agriculture is central to the Bank's objective of poverty reduction and indeed is closely tied to most of the Bank's work.

Norman Borlaug was the first keynote speaker. Addressing the problems of providing sufficient food grains to feed the burgeoning populations of the developing countries, particularly in Africa, he stressed the need for a substantial increase in investments in agriculture, rural education, primary health care, and community development.

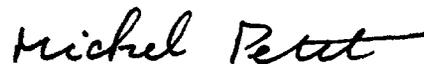
Vernon Ruttan, the second keynote speaker, also stressed agriculture's ability to respond to the demands of an expanded population, but noted that future food demands would be even greater and production increases more difficult to achieve.

The first plenary session concentrated on technology for the 1990s, examining the rate and potential limitation of technology generation. The second day's first session presented various perspectives on the GATT negotiations. Afternoon sessions highlighted agriculture, natural resources, and the environment in the 1990s, as well as the implications for agricultural development of the move of planned economies toward market-driven economies, focusing on Poland, the U.S.S.R., and China.

The final day of the symposium highlighted high-value crop and livestock products in the 1990s. Presenters examined recent advances in agroprocessing technology, how smallholders can become involved in agroprocessing, and prospects for high-value crops and related technology transfer.

In closing the symposium, I suggested components of a possible Bank strategy for financing agricultural development in the 1990s. This strategy must incorporate the Bank's two overarching objectives: poverty reduction and sustainable development. Embodying development issues in rural areas--where 60 percent of the developing world population lives--the Bank's agricultural strategy would include three elements: institutional and policy reforms, technology development, and resource conservation and management.

This volume contains papers presented at both the plenary and group discussion sessions. It is designed to be a permanent record to further enhance the knowledge of Bank staff working in agriculture and rural development and a means of exchanging knowledge with others working in agricultural development.



Michel Petit
Director

Agriculture and Rural Development Department

ACKNOWLEDGMENTS

The planning of the Eleventh Agricultural Symposium was the responsibility of a working group composed of representatives from various Bank departments. This group was responsible for suggesting the theme of the symposium, developing the main subjects within the theme, and selecting speakers to present papers. Members of the working group were C. Antholt (ASTAG), R. Burcroff (AS3AG), C. de Haan (AGRPS), S. Deol (POPTR), P. Garg (EM3AG), O. Honisch (EMTAG), O. Knudsen (AGRAP), M. McMahon (LATAG), R. Nelson (AS4AG), S. Oliver (LA4AG), A. Pritchard (AGRPS), A. Seznec (AFT), P. Tamboli (AS5AG), and D. Van Der Sluijs (LALAG).

The symposium was sponsored by the Bank's Agriculture and Rural Development Department and its Training Division, which, along with the Publications Department, produced this volume.

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OPENING REMARKS

Barber B. Conable

In this, my fifth opportunity to address the agriculture symposium, rather than talk only about the importance of agriculture to development--something on which we all agree--I would like to also talk to you more generally about the changes taking place in the world and their impact on the Bank's work.

Historic changes are shaping our approach to meeting the challenge of development. People everywhere--most obviously in Eastern and Central Europe, but also in Latin America, Africa, and Asia--are trying to take control of their own destinies. Political pluralism and economic pluralism are marching in step. But these historic changes can be sustained only if we can reverse the inexorable march of poverty.

The World Bank offers the unique combination of experience, skills, and organized inputs needed in these countries seeking economic reform. Recent events confirm that the world depends upon us. Our membership is increasing: Czechoslovakia, Bulgaria, and Namibia joined the World Bank in 1990; Switzerland, Mongolia, and Albania are coming along and inevitably are going to join in the near future. Hovering in the wings is the Soviet Union.

Needless to say, the changes taking place in the Soviet Union have attracted a great deal of attention and interest. Negotiations surrounding a possible Soviet application for membership in the Bank, which has been decided in principle by the Soviets, are likely to be difficult and protracted because of the discussions about the Bank's capital and shareholding structure that would be involved. Meanwhile the Bank would not be able to make loans to the Soviet Union to help with its major restructuring problems, but we could provide, under the right circumstances, the technical cooperation that has been officially requested by the Soviets. Agriculture would be important in the technical assistance that the Soviet Union may want. We will have to consider the Soviet request as we proceed. The joint study on the Soviet economy has been completed, and there will be follow-up. Much is changing, and we will be tested in many ways as we consider the possibility of a closer relationship with the Soviet Union.

The denouement of the Gulf crisis either is imminent or will be difficult and protracted. The events in the Gulf will impact our member countries in ways that will require the Bank to respond in a responsible and measured way. If there is not a sharp resolution of the crisis, we will probably have to try to raise additional concessional funds to fill some of the financing gap caused by the tremendous dependence on oil--one of the elements in development and the very fragile financing formulae with which many of our poorest countries contend. These countries are all in the spot market now, running up unexpected expenses.

Another recent change that has enhanced our development work is the establishment of the Global Environment Facility. Four years ago environmentalists thought the World Bank was the villain with the black moustache. Some may still think so, but now the Bank has been given responsibility for administering the Global Environment Facility, in cooperation with UNDP and UNEP. This represents a dramatic change in the way people view the World Bank's role in resolving environmental problems.

Barber B. Conable is president of the World Bank.

The GEF is needed to help developing countries deal with environmental concerns that transcend national boundaries. There was a successful donors meeting in November on establishing a GEF of significant dimension, and it probably will be in operation by April 1991. The Bank is prepared to respond to this increased expectancy in dealing with global environmental problems and will continue its work on national environmental programs as well.

Whatever external shocks or changes occur in the world that require our attention, the World Bank must remain true to its central development mission of reducing poverty. Poverty reduction continues to be the integrating theme for everything we do. Last year's World Development Report set out a clear strategy for reducing poverty. There are two parts to that strategy: first, strong economic growth that increases income-earning opportunities for the poor, and second, development of human resources to enable them to exploit these opportunities. Perhaps the report does not really pioneer much; but it does restate the fundamentals, and we have been able to buttress them with concrete evidence of what works and what does not.

In the least developed countries, agriculture remains the main engine of growth. We must use the assets already in these countries--the skills, traditions, and resources--and that means we have to continue working on agriculture. Indeed, there is a close association between agriculture and almost every sphere of our work. Much of the Bank's policy work in adjustment lending is aimed at stimulating agricultural growth--including, for example, our trade liberalization work. Of course, the importance of agriculture in international trade goes beyond developing countries--witness, for example, the GATT negotiations, whose success or failure depends on agriculture.

We must provide the right incentives to farmers, targeting urban poverty in ways that will not work against rural poverty and that will encourage a supply response. Our lending for transport also supports agriculture, bringing inputs to the farmer and production from the farmer to the market. Similarly, our increased focus on education is necessary if agricultural inputs are to be improved and better organized. Agriculture is the opening wedge for dealing with an extension service that becomes a valuable tool in the social sectors such as health, nutrition, and family planning, as well as education itself.

Agriculture is also critical to the environment, as it is critical to development. Indeed, the environment challenge is itself a development issue. Poverty is a toxic force bearing on the environment; poor people are the least able to adapt to environmental degradation, whether global or local. There is a close nexus between population growth and land pressure and between agricultural technology and appropriate land use.

We face many challenges and opportunities in agriculture. Research and extension require intense efforts to improve productivity. We are articulating a forestry policy as we must do urgently. The forest constitutes a resource that poor people need to use in a way that will be, if not totally ecologically neutral, then at least not ecologically destructive. We also need to sharpen the focus on maintenance and operational efficiency in irrigation and drainage, and in transport, but we have to have a solid basis for sustaining it. The routine and sometimes more modest things we do are very important. Voltaire, my favorite character in history, was once told by an admirer that he had done a lot for posterity, and his response was, "Yes, I've planted 4,000 trees." Voltaire did do a lot for posterity beyond planting trees, but the more direct practical things we do often have the greatest impact on peoples' daily lives.

As the world is changing, the Bank must demonstrate its capacity to change in ways consistent with its long-term development goals. We must continue our high-quality analytical work; our nonlending advisory role is expanding much faster than our lending role. Indeed, total lending by the

IBRD declined last year for reasons of country performance. Aggregate lending is not as important, however, as the quality of the work we do. Admittedly, there is some cynicism about this in the Bank, and there may be a need for cultural change--from a culture of lending to a culture of implementation and country performance.

There is concern, as noted in the sector review, about the decline in our agricultural lending and about the failure rate. Just as we must focus on the quality of our lending rather than the aggregate amount, so must we improve the methodology for measuring our outputs. I am pleased that we now have a task force to review how we can reflect more accurately in our budget what the Bank is actually doing rather than simply rely on the aggregate statistics of a number of our loans and their volume. For instance, in agriculture our staff intensity is increasing because we are dealing with smaller projects in Africa instead of the massive projects we previously dealt with in India. Such things as an analysis of our technical assistance and staff intensity should be used to judge our own performance.

The issue of failure rates requires some review of the evaluation methodology. For instance, there is something wrong if the economic rate of return for a project of 10 percent or less is considered a failure, and 11 percent a sparkling success. In Mauritania, for instance, a 10 percent economic rate of return on an agricultural project would be good. We also measure a 20-year rolling average so there can be sharp improvement in practice with little change in aggregate statistical assessment of failure or success. The Bank establishes a projected economic rate of return at the time we approve a loan, and OED measures the success of the loan when the loan is closed rather than when the project has lived its useful life. Obviously we do not want to have to go back 30 or 40 years to decide whether we have had a success or failure. Moreover, how should the many uncontrollable externalities involved in these calculations be accounted for? Of course, the basic objective should be to gauge the economic return of a project with a greater degree of success than we do at the time the loan is made.

As an institution we should deal with some of these issues internally in better ways, paying particular attention to nonlending and implementation. We must also have strong and effective collaboration among the different parts of the Bank. When we reorganized, we deliberately decentralized our function, strongly emphasizing the focus on the specifics of member countries, with decisionmaking delegated to the country level. But we are not and cannot function effectively as a series of disconnected organizations with different standards and goals. We must maintain an institutional coherence, while striving to reduce the amount of bureaucratic review and to reflect the tremendous diversity among our clients.

One thing that emerges from a symposium of this sort is the sense that we are one institution--that we have much in common--that we are not just doing our individual work in a niche somewhere, accountable only to ourselves and our conscience. We are part of an institution with solid global credentials based on experience and a strong commitment to development and the reduction of poverty. The World Bank must continue to reflect a changing world, to maintain its relevance, to continue to draw on the tremendous diversity that exists outside and within the Bank, and to accept responsibility for being central to the development process.

SESSION I:
KEYNOTE SESSION

**REACHING SUB-SAHARAN AFRICA'S SMALL-SCALE
FARMERS WITH IMPROVED TECHNOLOGY:
THE SASAKAWA-GLOBAL 2000 EXPERIENCE**

Norman E. Borlaug

Africa's Development Crisis

Robert McNamara, in his address to the Africa Leadership Forum in Nigeria in June 1990, identified the three major factors underlying Africa's development crisis: agricultural stagnation, population explosion, and environmental degradation. To these three factors must be added abject, stultifying poverty, which defies solution and imprisons hundreds of millions of subsistence farmers in perpetual poverty. Indeed, as McNamara stated, "Sub-Saharan Africa unquestionably poses the greatest development challenge facing the planet today" (McNamara 1990). Almost every social, economic, and environmental indicator has worsened in Sub-Saharan Africa over the past three decades. Poverty, sickness, and hunger are rampant; economies are moribund; agricultural production is stagnant if not declining; and the "population monster" is causing environmental degradation on an unprecedented scale through deforestation, desertification, and soil erosion.

Despite the fact that 70 to 85 percent of the people in most Sub-Saharan countries are farmers, agricultural and rural development has been a low priority, and governments have frequently pursued impractical, idealistic goals. Public investments in agricultural research and production, primary education, and community development have been woefully inadequate. Furthermore, cheap-food policies to appease the politically volatile urban dwellers have greatly distorted production incentives for farmers and have served as a disincentive to adopt more modern crop technologies.

Despite the formidable challenges of tropical Africa, many of the agricultural development elements that have worked in Asia and Latin America will also work there. To capitalize on the unexploited agricultural potential of Sub-Saharan Africa (excluding the Sahel)--and on the significant technologies in the research pipeline--continued investment in agricultural research and extension, input supply, and grain marketing and storage systems is essential. This must be complemented by economic policies that stimulate agricultural productivity in ways consistent with the wise use of natural resources.

Pursuing policies that encourage higher production without introducing technologies that will increase yields and reduce costs will defeat the purpose. The evidence of the green revolution is that improved technology and effective policy must go together; manipulation of prices alone will not ensure success in agricultural development. Development of improved technology, however, does not necessarily ensure its adoption by most farmers. In many cases, researchers have developed improved technologies for Sub-Saharan farming systems, yet sadly, few of these "research products" are being extended to farmers. Linking agricultural research and production activities to promote the generation and dissemination of more effective technology remains a major institutional challenge facing policymakers concerned with reversing Africa's current tragic decline in human welfare and arresting the unprecedented environmental degradation being wreaked upon this continent.

Norman Borlaug is president, Sasakawa Africa Association; distinguished professor of international agriculture, Texas A&M University; and consultant, International Maize and Wheat Improvement Center.

This paper reviews some of the key biological factors constraining yields, describes the work and progress of Sasakawa-Global 2000 agricultural projects, and shares some conclusions and questions that have emerged from this work.

Biological Factors Constraining Yields

To achieve the agricultural productivity gains needed in the low-income, food-deficit countries of Africa, a combination of biological factors constraining yield must be manipulated and overcome in an efficient and orchestrated manner. These include (a) restoration and management of soil fertility; (b) development and use of improved crop varieties (and animal breeds), combining higher genetic yield potential and yield dependability with improved disease and insect resistance; and (c) improvement of crop management practices, including integrated pest management and soil fertility management programs.

Low Soil Fertility

Without doubt, the single most important factor limiting crop yields in Africa's more or less 700- to 1500-mm rainfed belt is low soil fertility, caused by natural soil infertility, extractive farming practices, or deficiencies of specific nutrients brought on by more intensive farming practices. Traditionally, tropical Africa's shifting cultivation and complex cropping patterns have permitted low, but relatively stable, food production. However, expanding food requirements have pushed farmers onto more marginal lands and have led to a shortening of the bush/fallow period needed to restore soil fertility. With more continuous cropping on the rise, nitrogen and organic material are being rapidly depleted, and phosphorus and other nutrient reserves are also being depleted slowly but steadily. The shortening of the bush/fallow period is leading to serious erosive soil loss, weed invasion, and fire-climax vegetations of an impoverished nature.

Nitrogen is the most common limiting nutrient for cereal production in tropical ecosystems, where most of the N (often 90 percent) is found in the living plants themselves with only a fraction actually mineralized in the soil. This situation is in striking contrast to temperate soils, where the reverse ratio is more typical, with most N mineralized in the soil. The relatively meager mineralized nitrogen in tropical soils is often readily leached out and also lost through denitrification, volatilization of ammonia, and other pathways. Because nitrogen uptake is essentially linear with increasing grain yields, it provides the major difference between low- and high-yielding cereal crop cultivation. Phosphorus is the second-most common limiting plant nutrient for cereal grains. Despite the abundance of phosphorus in most soils, tropical African soils--especially the acidic ones--have a high capacity for immobilizing or "fixing" phosphorus; without supplemental applications, phosphorus deficiencies will constrain food crop yields regardless of the amount of nitrogen applied.

Although there is irrefutable scientific evidence that chemical fertilizers--used wisely--do not harm the soil, some organic gardening enthusiasts insist that the wide use of organic fertilizer could provide the nitrogen needed to produce sufficient food for the world, including Sub-Saharan Africa. This, of course, is not so. For centuries the Chinese, Japanese, and South Koreans have done an excellent job of maintaining a moderate level of soil fertility through the use of organic wastes and residues. But today, even in these countries, large amounts of chemical fertilizers are used to achieve high yields. Luckily, soil fertility can be restored effectively by applying the right amounts of the right kind of fertilizer--either chemical or organic, or preferably, a combination of the two--according to the requirements of different crops, soil types, and environments.

Use of Traditional Varieties

Traditional or landrace crop varieties have generally evolved on nutrient-depleted soils. They have a low genetic grain yield potential and unfavorable grain-stover ratios. When soil fertility is restored, traditional varieties respond poorly, manifesting various structural, physiological, and pathological weaknesses. They grow tall, have weak stems and stalks that cause them to lodge badly, and are vulnerable to many epidemic diseases and insect pests. Once soil fertility is restored, it is therefore necessary to develop and distribute a series of high-yielding, disease- and insect-resistant crop varieties with acceptable agronomic and consumer quality characteristics.

Although much work remains to be done, many improved crop varieties have been developed by national and international agricultural research organizations for Sub-Saharan Africa. Compared with most traditional varieties, today's new cereal crop varieties are vastly more efficient in grain production and carry much higher levels of genetic resistance to diseases and insects and tolerance of various agroclimatic stresses. Unfortunately, except for a few countries--notably Zimbabwe, Kenya, and perhaps Zambia--few returns are accruing to farmers from these investments in plant breeding research. In maize, for example, although nearly 60 percent of the total developing country area is planted with improved genotypes (mostly hybrids), only about 25 percent of the Sub-Saharan maize area is planted with improved materials.

Adoption of improved food crop varieties in Sub-Saharan Africa has been retarded by various factors. Because many African farmers operate on the fringe of the commercial agricultural sector and consume most of their harvest on the farm, the purchase of improved varieties is more difficult. Until more small-scale farmers can participate more fully in commercial agriculture, adoption of improved varieties will be stymied. Soil infertility and lack of physical and/or economic access to fertilizers have also seriously hampered adoption of improved genotypes; until this pressing yield constraint is relaxed, the diffusion of improved crop varieties will be held in check because the yield advantage of improved genotypes is largely eroded when they are grown in impoverished soils under poor crop management.

Certainly, for some ecologies and farmer circumstances, the so-called improved crop varieties released by national and international research organizations have not been sufficiently superior to the traditional varieties in yield potential and yield dependability to merit adoption; unless plant breeding organizations develop more appropriate germplasm products for such areas, the farmer will continue to rely on traditional cultivars. There has been a particular lack of progress by international and national research organizations in developing improved sorghum varieties for many of Africa's rainfed environments. With the resources that have been invested in sorghum breeding research, more progress should have been made by now.

Low-Yielding Crop Management Practices

In the indigenous agricultural systems of Sub-Saharan Africa, the overwhelming deficiency of plant nutrients places such a limit on yield potential that the traditional farmer has learned that he or she can do little to increase crop yields by solely manipulating cultural practices. Consequently, seedbeds are often poorly prepared, resulting in patchy stands with poor spacing between plants. Little attention is given to conserving moisture (rainfall). Inadequate attention is paid to weed control because under low soil fertility weeds are not highly competitive with the crop plant, because they too are experiencing plant nutrient deficiencies.

Once soil fertility has been restored, improved crop management becomes crucial to capitalizing on the yield potential of the improved varieties. It is necessary to employ good seedbed preparation, proper seed

rates and the correct dates of planting for each of the improved varieties, and proper conservation and management of soil moisture. Weed control is also important because weeds become aggressive and highly competitive under improved soil fertility; unless they are controlled either mechanically and/or chemically, the farmer will harvest more weeds than food grains.

Disease and Insect Stresses

In low-yielding traditional agricultural systems only in unusual years are ecological conditions sufficiently favorable to produce seriously destructive insect infestations and disease epidemics. In most years, the insect pest and pathogen species, like the host plants, are all struggling for survival under difficult and unfavorable environmental conditions. The situation changes dramatically in more intensive agricultural systems. Fertilized soils and improved agronomic practices result in the development of thick, lush crop stands. Combined with the year-round warm temperatures of tropical Africa, the ecology within these fields then becomes very favorable for development of disease pathogens and insect pests.

Integrated pest control programs will be essential in Sub-Saharan Africa to stem potentially serious crops losses. Such control programs include the use of pest-resistant varieties, crop rotations, soil tillage management, biological control, and regular monitoring of the pest population combined with timely application of pesticides when necessary to keep crop losses at acceptable economic levels.

Sasakawa-Global 2000 Agricultural Program in Africa

Sasakawa-Global 2000 (SG 2000) operates agricultural development projects in Sub-Saharan African countries aimed at diffusing improved food crop technologies among small-scale farmers. These agricultural assistance projects are a collaborative effort of the Japanese philanthropist Ryoichi Sasakawa and former U.S. President Jimmy Carter.

Despite some differences, all SG 2000 projects share common elements. First, they are all concerned with improving productivity in the major food crops grown by resource-poor farmers. The aim is to help as many small-scale farmers as possible to become richer, more knowledgeable, and more in control of their economic destinies. This goal is pursued knowing that science and technology cannot solve all of the societal ills plaguing Sub-Saharan Africa. The technological change being promoted will invariably create some "losers," but there will be many more "winners" as the result of these efforts.

Second, the technology transfer work is focused in the more favorable production environments. With the exception of Sudan, where work is in the irrigated areas between the Blue and White Nile rivers, field testing and demonstration programs are conducted in rainfed environments with rainfall above 700 mm annually. These more favored agricultural environments have been selected first because of the larger number of rural people living in them and because more proven technology was available to extend within acceptable levels of risk for the small-scale farmer. Indeed, most of the varieties and crop management practices being promoted have been available for a decade, but were lying around, largely unused, on agricultural experiment stations.

Third, each of the projects is quite small, both in terms of staff and financial resources. Two to three internationally recruited scientists are assigned to each country project, where they work with the ministry of agriculture's national extension services and research organizations, which provide most of the human resources to carry out project objectives. Although crop scientists themselves, SG 2000 staff interface agricultural research with extension, functioning as technology transfer advisers within national extension services. Their charge is "to work themselves out of a job" as

national and international organizations integrate project principles and activities into their own program and institutional structures.

Fourth, an activist stance is taken in efforts to influence agricultural policy. SG 2000 does not accept the status quo; it is committed to influencing government investment decisions and increasing the amount of capital flowing into agriculture. It seeks to accelerate the development of agricultural institutions and infrastructure and is actively involved in lobbying political leaders--and working with them--to develop more effective systems to supply small-scale farmers with improved seed and fertilizer and to improve grain storage and marketing systems.

Program Organization and Activities

The heart of the SG 2000 agricultural projects is the field testing and demonstration programs, which involve extension officers, researchers, and thousands of small-scale farmers (generally 1- to 2-ha farmers employing hand tools). Initially SG 2000 focused on two or three major crops (mostly maize and sorghum) and emphasized basic improvements in crop management, such as the use of improved varieties, moderate amounts of the appropriate fertilizers, and improved and timely cultural practices.

The primary vehicle used to test and demonstrate these superior food crop technologies is the production test plot (PTP), which differs from those employed by other organizations in several important respects (table 1). The PTP program is a "production program" rather than solely a "technology demonstration" activity. Each farmer-cooperator is provided with the recommended inputs needed to grow a test plot, with the understanding that if he or she obtains substantial and profitable yield gain the cost of the inputs will be repaid, either in cash or in kind. SG 2000 is, in effect, entering into a cost-sharing partnership with the farmer to test the recommended production technology.

Compared with most other technology transfer programs, the SG 2000 PTPs are relatively large--0.4 to 2 ha--depending on the prevailing farm size in each country. These larger plots provide an immediate and sizable economic benefit to the cooperating farm family, adding 1 to 2 tons of grain. The psychological impact of such production gains is important in convincing the individual farmer and in making him or her an enthusiastic "promoter" of the new technology among neighboring farmers. Normally, after two years of participation in the PTP program, the farmer is "graduated" and must secure inputs and credit on his or her own, although the extension officer continues to provide technical backstopping.

Table 1. SG 2000 PTP Program and Other Extension Demonstration Programs

<u>Feature</u>	<u>SG 2000</u>	<u>Other programs</u>
Average size of plot	0.4 to 2 ha	0.1 to 0.2 ha
Provision of recommended inputs on credit	Yes	No
Active participation of farmer and use of own land	Yes	Sometimes
Proportion of farmers in target area who participate in PTP program over 5 years	12-15%	1-2%
Use of PTPs for farmers' field days	Extensive	Moderate
Efforts to involve political leaders in PTP program	Aggressive	Passive

Each PTP farmer is asked to involve at least 10 neighbors in the observation and evaluation of his or her production test plot. To illustrate the yield differences, the farmer is asked to plant a companion plot adjacent to the PTP employing his or her indigenous technology. SG 2000 staff have made a special effort, when culturally possible, to involve women farmers in the field testing program. In Ghana and Tanzania, for example, about 25 percent of the PTP participants are women.

Program Accomplishments

More than 140,000 small-scale farmers in Ghana, Sudan, Zambia, Tanzania, Benin, and Togo are alumni of the technology testing/demonstration programs in several basic food crops, including maize, sorghum, wheat, cowpea, and soybean. These PTP programs, conducted in close collaboration with ministries of agriculture, have been primarily financed with national resources (table 2).

By employing a simple package of improved technology, cooperating farmers have obtained yields two-to-four times greater than previously obtained with their traditional technology (table 3). With these production gains, farmer enthusiasm for the recommended technologies is very high and as great as that observed in India and Pakistan during the green revolution of the 1960s.

Table 2. Farmers Participating in PTP Program

Country	1986	1987	1988	1989	1990	Total
Ghana	40	1,600	16,500	85,000	25,000	128,140
Sudan	430	1,885	2,655	600	600	6,170
Zambia	--	252	1,100	1,400	1,400	4,152
Tanzania	--	--	--	67	1,800	1,867
Benin	--	--	--	85	1,870	1,955
Togo	--	--	--	--	64	64

-- Not applicable.

Source: SG 2000 data.

The impact on maize and wheat production in Ghana and Sudan, respectively, during the past five years has been substantial and indicates that at least some components of the technologies recommended by SG 2000 are being used by farmers, both within and outside the field testing program. Since 1985, maize production in Ghana has increased by more than 75 percent, and wheat production in Sudan has increased by 130 percent (table 4).

SG 2000 has begun to set the farming "grass roots" on fire, and it is heating up for the policymakers. Tens of thousands of farmers, convinced of the superiority of the production technologies demonstrated through the SG 2000 program, want access to the needed inputs; they will not easily revert to their previous low-yielding traditional technologies.

During 1990, several independent studies (SG 2000 External Review Team; CIMMYT/CRI adoption study) were undertaken in Ghana to assess the adoption of production technologies and the efficacy of the SG 2000 technology transfer model. An economic policy study (CIMMYT) is also under way in Sudan to assess the benefits of self-sufficiency in national wheat production versus promotion of alternative crop production in the irrigated areas.

Table 3. Estimated Average Yield in Production Test Plots (PTP) versus Farmers' Plots Using Traditional Practices (FP) in Ghana, Sudan, and Zambia, 1987-89

Country	Crop	Test plots (approx. number)	Average yield, t/ha		% gain PTP over FP
			PTP	FP	
Ghana	Sorghum	35,000	1.7	0.6	183
	Maize	90,000	2.7	1.2	125
Sudan ^a	Sorghum	3,200	3.3	1.3	154
	Wheat	3,000	3.1	1.3	138
Zambia	Maize	3,000	4.3	1.7	153
	Sorghum	1,200	3.2	1.1	191

a. Irrigated production.

Source: SG 2000 data.

Table 4. Production of Wheat in Sudan and Maize in Ghana

Country/Crop	1985	1986	1987	1988	1989
Sudan: wheat					
Area, 000 ha	151	118	144	198	275
Production, 000 t	200	157	181	258	460
Yield, kg/ha	1.3	1.3	1.3	1.3	1.7
Ghana: maize					
Area, 000 ha	405	472	548	540	567
Production, 000 t	395	559	598	751	715
Yield, kg/ha	1.0	1.2	1.3	1.4	1.3

Source: National Agricultural Production Statistics.

Despite many challenges ahead to institutionalize the technology transfer model and to build a firm base for sustained adoption of yield-increasing technologies in Sub-Saharan Africa, the SG 2000 programs have demonstrated that:

1. Improved food crops production technologies developed by national and international agricultural research organizations are appropriate for use by small-scale farmers and have the capacity to double, triple, and even quadruple farm grain yields in Sub-Saharan Africa; as a second step toward increasing farm family income in areas where land availability is not a serious constraint, an economically feasible animal-powered (or small tractor) technology must be developed to permit an expansion in the small-size "hoe-machete" farm of 0.4 to 2 ha to a 4- to 5-ha animal-powered farm, with a corresponding increase in production and family income;
2. Sub-Saharan farmers, when provided the necessary technical information, inputs, and credit, are eager and capable of adopting higher-yielding production technologies and in serving as enthusiastic "promoters" of technology diffusion;
3. Ministry of agriculture extension officers, when empowered and motivated through on-the-job training, improved mobility, and a dynamic technology transfer model, can be effective catalysts in assisting small-scale farmers to transform the low-yielding

agricultural systems that the "population monster" has rendered unsustainable.

The "Appropriate Technology" Debate

Despite the eager participation of tens of thousands of small-scale farmers in the SG 2000 programs, the appropriateness of promoting the seed-fertilizer technologies remains controversial for some agricultural development specialists. The most strident critics flatly say that chemical fertilizers and plant protection chemicals will never be appropriate technologies in Sub-Saharan Africa and that they pose grave environmental dangers. Others view the use of purchased inputs, especially agricultural fertilizers and chemicals, as "advanced" technologies suitable only for resource-privileged African farmers operating in advanced, well-developed commercial agricultural sectors. Similar criticisms were leveled at the use of improved seed-fertilizer technology and improved management practices during the early years of the wheat revolution in India and Pakistan in the mid-1960s.

In his 1987 Science article, IITA soil scientist Rattan Lal contends that, because resource-poor farmers cannot afford to purchase chemical fertilizers, the first step in improved soil fertility management should be "low-cost" technologies, such as conservation tillage (minimum or no-till), mulch farming, ley farming (growing food crops through lightly grazed pastures in a no-till system, as practiced in Australia), or intercropping with trees and deep-rooted legumes. As low-yielding subsistence agriculture is transformed into high-yielding commercial agriculture, farmers would progress through various steps until they eventually adopted "advanced" technologies based on use of chemical amendments, mechanization, etc.

On the surface, Lal's argument for the initial adoption by resource-poor Sub-Saharan farmers of improved "low-cost" and "low purchased-input" technologies for soil fertility management makes sense. The flaw in this strategy is that these "low-input" technologies turn out to be more "knowledge-intensive," requiring well-developed institutional extension structures and considerable time to disseminate the necessary information, than do the so-called high-input, fertilizer-improved seed technologies.

More than 20 years ago, CIMMYT made a concerted but unsuccessful five-year effort to introduce the ley-legume-sheep-wheat system (led by a capable Australian scientist thoroughly familiar with the system) among small-scale farmers in several countries of North Africa and the Near East. Despite a talented team and the fact that the Australian cultivars of subterranean clover and annual medics came originally from these geographic areas, the technology took more than 20 years to gain commercial acceptance among these resource-poor farmers, largely because the system was complicated and required considerably higher management skills.

The alley cropping technology developed by IITA is a good example. It involves growing crops such as maize in "alleys" between nitrogen-fixing leguminous hedgerow crops such as Leucaena. There are many potential benefits of this technology: improved soil conservation, nitrogen fixing, and provision of mulch and fuelwood. But after 15 years of research and promotion very few African farmers have adopted alley cropping. Why? Part of the problem is that the nitrogen fixed by the intercropped leguminous plants does not increase yields sufficiently to induce farmers to establish and carefully maintain the hedgerow crops so that they do not compete with the food crops. Second, although the technology requires less outlay for nitrogen fertilizer (phosphorus and other plant nutrients will have to be applied eventually) compared with conventional technologies, successful implementation requires crop management skills that exceed the capacity of most small-scale farmers to assimilate and of extension education programs to demonstrate on a large scale. Third, land tenure factors will all but preclude the adoption of alley cropping on rented and share-cropped land.

I do agree that "transformation of low-input subsistence agriculture can be done through gradual improvement and by technological innovations appropriate for different stages" (Lal 1987). I would suggest there is a different sequence, however, starting with fertilizer-improved seed technologies where more of the yield gains are inherent in the inputs themselves. The adoption of technologies built around more ecologically compatible cropping systems, soil and moisture conservation, reduced input use, and integrated pest management is more likely at later stages and among relatively advanced commercial farmers who possess more sophisticated crop management skills and seek new technologies to lower production costs. Unless general and technical agricultural educational levels are vastly improved in the low-yielding subsistence agricultural economies of Sub-Saharan Africa, few of the new cost-reducing "environmentally friendly" crop technologies being developed by agricultural scientists--such as integrated pest management and greater use of crop rotations, organic manures, and residues to maintain soil fertility--will go beyond the research station.

Small-Farmer Credit

Credit should be extended on the basis of the potential for increasing and sustaining the well-being of farmers. The primary objective should be to help the farmer increase the value of output more than the increases in input costs, leaving him or her with a net gain. Formal agricultural credit programs have difficulty serving small-scale farmers, who often lack tangible assets or a clear title to their land as collateral. Their repayment capacity is also limited, especially when traditional food crops are produced and when direct consumption absorbs a large part of production. For these reasons, a minimum farm size is often recognized by credit programs.

Nevertheless, the SG 2000 experience over the past five years indicates that production credit is very important if farmers are to make greater use of purchased inputs. A high percentage of small-scale food producers in the more favored environments are creditworthy, provided credit sources are accessible, credit arrives on time, and its use is properly monitored.

Several serious obstacles, however, must be overcome if small-scale farmers are to become regular users of production credit. One of the greatest challenges to establishing effective credit systems for small-scale farmers is finding ways to cut overhead administrative service costs inherent in extending many small-denomination loans, while maintaining effective supervisory and monitoring control. The obvious solution is to organize farmers into groups to promote collective action. The many past abuses by the leadership of small-scale farmer cooperative societies and the tendency to create these organizations by government from the top down, along with the widespread and lingering high rural illiteracy rate, make the task of developing "grass roots" farmer credit societies difficult, but not impossible. Expanded rural savings and credit organizations remain one of the great community development challenges. There are many millions of 1- to 2-ha farmers scattered throughout Sub-Saharan Africa who can make profitable use of production credit: their needs cannot continue to be ignored.

Seed Industry Development

One of the least expensive technological components that a small-scale farmer can adopt is improved seed. Widespread adoption of improved genotypes, however, requires the development of seed organizations that can efficiently produce and distribute quality seed in a timely fashion. For hybrids, a functioning seed industry is a prerequisite for development of a market. Even for open-pollinated varieties, a functioning seed industry is almost as important, because the yield advantage of improved open-pollinated varieties is easily diluted by mechanical mixing or by pollen contamination from indigenous genotypes grown in the immediate vicinity.

Experience in many developing countries has shown that, with few exceptions, governmental seed organizations that exercise monopoly control over seed production and distribution become complacent and bureaucratic and produce seed of poor quality. Often, despite huge capital investments in the most modern equipment and in training of technical staff, the seed of improved crop varieties produced by these public sector organizations is mixed for phenotype, has low germination, and frequently carries noxious weed seeds. During the past four decades in three particular instances in different countries, SG 2000 was involved with wheat production programs in which seed of poor quality with ruinously low germination was received, originating from monopolistic government seed organizations.

Some countries have alleviated this shortcoming by distributing part of the breeder and basic seed from public sector breeding programs to farmers' cooperative seed organizations or to private seed companies with skilled and motivated employees who adequately supervise the multiplication, harvesting, processing, storage, and distribution of quality seed. All of the large shipments of the high-yielding Mexican semidwarf wheat seed (5,000 to 32,000 tons) that went from Mexico to Asian and Latin American countries in the 1960s, and which gave rise to the so-called green revolution, were produced, processed, and exported by Mexican farmers' cooperatives and arrived at their destinations in good condition.

The lack of good seed production systems in Sub-Saharan Africa still is a serious impediment to increasing food production in most countries. During the past five years, the Sasakawa-Global 2000 production test plot program has served as an artisan seed production and distribution program of new improved varieties to small-scale farmers. More permanent seed systems, however, are needed to bring the fruits of plant breeding research to the farmer. The long-term seed development strategy should be to encourage public-private sector cooperation in research and seed production, with private sector organizations increasingly taking over responsibilities for seed production and distribution. However, the development of the overall market demand for improved seed, especially among small-scale farmers in undeveloped Sub-Saharan Africa, will not occur overnight. To expand the rate of diffusion of improved crop varieties over the next decade, continued public sector financial and policy support will still be needed to help private sector seed industries to develop.

Fertilizer Sector Development

Chemical fertilizer use in tropical Africa is the lowest in the world, averaging less than 8 kg per hectare (arable land and land in permanent crops), with most destined for higher-value export crops. Despite this very low level of fertilizer use in tropical Africa, especially on food crops, knowledge of the benefits of fertilizer use is sufficiently widespread to allow for accelerated growth of adoption during the next several decades. As fertilizer use increases, however, farmers and agronomists will need greater soil chemistry skills to deal with the growing primary, secondary, and micronutrient deficiencies that must be corrected to sustain high grain yields.

Sub-Saharan Africa only produces 20 percent of its fertilizer requirement, compared with a 75 percent self-sufficiency rate for the developing world as a whole (FAO 1987). Fertilizer production facilities are virtually nonexistent in most countries, and those few that are in place are either underutilized or out of use because of technical problems. An exception to this dismal picture is the new modern ammonia-urea fertilizer complex in Nigeria.

The International Fertilizer Development Center (IFDC) has estimated that fertilizer use must triple in Sub-Saharan Africa between 1980 and the year 2000, although even this expansion will not result in food self-sufficiency. However, if fertilizer demand does not expand, Sub-Saharan

Africa, as FAO Director General Eduardo Saucma has warned, may be only producing 75 percent of its food requirements by the end of the century, clearly an untenable situation for any low-income agrarian country with foreign exchange problems.

Fertilizer Subsidies: Are They Necessary?

The trend in Sub-Saharan Africa toward privatization of agricultural input distribution and the closing of poorly administered and unresponsive parastatal companies are a welcome development. In the long run, increased private sector activity in fertilizer supply should improve efficiency and lower the costs of delivering nutrients--benefiting farmers and consumers alike. But what are the short-run implications of removing subsidies?

The radical reduction of fertilizer subsidies by Sub-Saharan governments has had a negative effect on the economics of fertilizer use, even in the relatively well-watered environments. In Ghana in 1987, for example, SG 2000 began by recommending a fertilizer dosage of approximately 100 kg of N/ha and 50 kg of P₂O₅/ha, at a cost of about \$60/ha (nutrient-to-grain ratio = 2:1). In 1990, that same fertilizer dosage cost about \$120/ha (ratio = 4:1). A profitability analysis of two levels of fertilizer pricing for two fertilizer recommendations is shown in table 5. Clearly, the removal of subsidies has rendered the more agronomically optimum fertilizer dosage uneconomic.

In 1990, with World Bank urging and pressure, the government of Ghana eliminated most of its subsidy on fertilizer sold at government farm input-supply outlets, retaining only subsidy on the cost of transporting fertilizer to locations in the interior of the country. As soon as possible

Table 5. Partial Budget Profitability Analysis of Different Maize Production Technologies in Ghana under Two Levels of Fertilizer Pricing

	Changes in practice:	
	Treatment 1 to 2	Treatment 2 to 3
<u>Fertilizer nutrient-to-maize grain ratio = 2:1</u>		
Marginal costs,		
Cedis/ha	12,620	5,420
Marginal net benefits,		
Cedis/ha	42,380	9,010
Marginal rate of return to additional investment, %	226	66
<u>Fertilizer nutrient-to-maize grain ratio = 4:1</u>		
Marginal costs,		
Cedis/ha	20,420	16,805
Marginal net benefits,		
Cedis/ha	34,580	8,195
Marginal rate of return to additional investment, %	69	-49

Treatment 1 = Improved low-input package: use of improved open-pollinated variety and optimum plant density and row planting; average maize grain yield = 1.6 t/ha.
 Treatment 2 = Treatment 1 plus 53-25-0 kg of nutrients/ha; average maize grain yield = 2.7 t/ha.
 Treatment 3 = Treatment 1 plus 106-50-0 kg of nutrients/ha; average maize grain yield = 3.2 t/ha.

Source: SG 2000 data.

the government intends to get out of the fertilizer business altogether, transferring this activity entirely to the private sector.

The precipitous removal of subsidies has led to a dramatic drop in fertilizer consumption by Ghanaian farmers. In 1990, fertilizer consumption in Ghana--which had started to increase in the late 1980s--was less than 50 percent of the average use rate of the 1970s. Rapid price increases have all but crushed the still-infant fertilizer sector, leaving approximately 70,000 product tons of unsold fertilizer piled up and deteriorating in government warehouses. Had this fertilizer been used on food crops, perhaps an additional 200,000 tons of food grains could have been produced in 1990, benefiting the urban and rural poor alike. Instead--in the name of privatization and fiscal responsibility--Ghana now faces food deficits and will be forced to import maize and other grains by early 1991 to abate current prices for grain in the marketplace that are running much higher than normal. Of course, it is Ghana's poor who will bear the brunt of price increases resulting from inadequate grain supplies.

The present situation in Ghana poses the following questions for World Bank economists: (1) Are there no conditions under which fertilizer subsidies make societal sense? and (2) Is there some way in which subsidies, by helping to develop near-term fertilizer demand, can be beneficial to longer-term private fertilizer sector development? It is strange and hypocritical that the United States and the EEC can spend \$150 billion a year in direct and indirect production subsidies for their farmers while preaching so adamantly in Sub-Saharan Africa that agricultural production subsidies must be removed.

We are deluding ourselves if we think that the current "privatization" and "structural adjustment" development strategies in vogue today will produce magic and rapid results in the agricultural economies of Sub-Saharan Africa. Is there a middle-ground position that would permit a certain level of production subsidies that encourage small-scale farmers to adopt yield-increasing technologies? There could be disastrous consequences resulting from the current policy course, unless it is tempered by the realism of the near-term constraints.

A New Philosophy of Extension for Africa

Many have argued that extension officers should strictly avoid any involvement with the farmers they serve in the disbursement of agricultural credit, input distribution, and grain marketing. Their reasoning is that the extension agent is a "technical information specialist" and should devote all of his or her time to that activity, leaving other organizations to worry about production loans, input supply, and grain marketing.

The Sasakawa-Global 2000 programs do not share this limited vision of extension, especially for low-income, food-deficit African countries that lack the organizations to undertake many of these agricultural production-support activities. Although the primary efforts of extension officers should be focused on the informational dimensions of technology transfer, these "change agents" must play a broader development role over the next decade if peasant food production systems are to be modernized.

The U.S. Extension Service, especially during its early years, played a very important role in rural development. While involved in field programs to demonstrate improved agricultural technology--basically through on-farm demonstration plots--county extension agents and specialists at the agricultural universities helped American farmers to establish cooperatives and grain marketing boards, production credit associations, rural electrification associations, and soil and water conservation districts. As these rural organizations and institutions became more established and formalized, the direct involvement of extension service officers declined, and professional management was hired to guide and expand operations.

There is nothing wrong with extension officers having access to operating funds to finance and supply PTP farmers with the inputs needed to test the recommended technology. Such assistance is often necessary to empower farmers to test the new technology correctly, and it helps to develop the extension officer's credibility and effectiveness within the farming community. Of course, the primary role of extension officers as information-transfer agents must not be subverted, by turning them into commercial credit agents, input suppliers, and grain merchants. In the SG 2000 experience, each extension officer can manage 15 to 25 production test plots, as long as a minimum of mobility is provided (bicycle or motorbike).

When a technology testing and demonstration program in which inputs are loaned to farmer-cooperators grows too large, it quickly becomes a production credit program subject to many unwanted pressures, favoritism, and possible corruption. Many of these "management" problems have been encountered in Ghana, where the enthusiasm of extension officers and desire of farmers to participate in the PTP program led to a fourfold increase, growing from 16,500 plots in 1988 to 85,000 in 1989. In one year the number of PTPs under the responsibility of each extension officer increased from about 20 to over 100, creating an unmanageable administrative burden. Consequently, extension officers had less time for careful selection and proper technical backstopping to participating PTP farmers. The result was that loan recovery in 1989 dropped to about 40 percent, compared with 85 percent loan recovery in 1988 and even higher rates in previous years.

Agricultural Education and Training

Agricultural education in Sub-Saharan Africa is generally weak and poorly funded. Many of the staff of national research and extension organizations are inadequately trained to develop and transfer a continuing stream of improved yield-increasing, cost-reducing technologies. These deficiencies in agricultural education cannot be corrected in just a few years, for they reflect weakness in the general education systems in Africa that date back to the colonial period and that were not remedied following independence.

Financial support for education at all levels is seriously deficient. Primary schools in the rural areas, where 70 to 85 percent of the population lives, are inadequate in number. As Robert McNamara has noted, Sub-Saharan Africa will be the only third world region without universal primary school education at the end of this century. The situation with secondary schools in small towns and villages is even worse than that of the primary schools. Almost paradoxically, most African countries have colleges and universities that award degrees in the arts, law, medicine, engineering, science, agriculture, etc., for an elite few.

Graduates from agricultural universities in Africa generally have rather good theoretical training in agricultural sciences but invariably are handicapped by lack of experience with production agriculture, because with few exceptions they were born and reared in cities. However, few young people from rural areas with agricultural experience can qualify academically for university entrance. The consequence of this dilemma is that most agricultural university graduates who assume research positions are poorly prepared in problem solving and practical technology development.

This situation will not easily be corrected, because there are few African universities south of the Sahara that offer graduate degrees in agricultural sciences. Over the past two decades, the international agricultural research centers (IRRI, IITA, CIMMYT, ICRISAT, etc.) have attempted to fill this void by providing 4- to 6-month, "hands-on" apprenticeship training scholarships to several hundred (perhaps thousand) young African agricultural researchers. But these training scholarships were never meant to be a substitute for study toward an advanced degree (M.Sc. or

Ph.D.) at a good graduate school in a top-flight university to prepare young scientists for leadership in national research and educational institutions.

Thirty years ago, it was not only possible, but almost automatic, for African, Asian, and Latin American graduate students to receive excellent and "appropriate" scientific instruction and training--relevant to their home countries' needs--in graduate schools in Western European, Canadian, Australian, and American universities. This is no longer true. Today, these developed-country agricultural universities find themselves confronted with huge food and agricultural surpluses. As a result, their research and instruction have been reoriented toward more fundamental, abstract, and esoteric aspects of agricultural sciences, as emphasized by Walter Falcon in his 1989 address to the American Society of Agronomy. This new focus in developed-country agricultural institutions does not coincide with the greatest needs of young African graduate students. All too often, these students are assigned research problems in molecular genetics and other biotechnology topics that are esoteric and of little or no value to meeting the food production challenges and current research skills and needs in the students' home countries.

This reorientation of instruction and research emphasis in developed-country universities makes their programs less relevant to the needs of young African students, especially those studying at the M.Sc. degree level, and indicates the need for developing strong, but practical, graduate training programs in several African universities--such as the one that was initiated at Makerere University in Uganda more than two decades ago, but destroyed during the revolution.

Moreover, it is time to develop at least two colleges of agriculture in Africa, with a curriculum at the undergraduate level similar to the Pan American School of Agriculture in Zamorano, Honduras. This college provides excellent academic training across a broad spectrum of instruction combined with "hands-on" practical training in the production of agricultural crops, fruitculture, horticulture, animal production, food processing, and forestry. The philosophy on which this course of study is based has certain similarities to the original course of study on which Kenya's Egerton College (now University) was founded.

Feeding the Future: The Challenges Ahead for Africa

The human population monster threatens the extinction of many other species, as well as the future advancement of human beings and world civilization on many fronts. Sub-Saharan Africa's population monster--with growth rates above 3 percent and 50 percent of the population under 15 years of age--is out of control and will not be easily tamed. Yet it must be tamed if Sub-Saharan Africa is to avoid social and political "melt-down" in the 20th century.

Those who work in agriculture (especially on the food production front), forestry, or wildlife conservation have a common responsibility to forcefully and repeatedly warn political, religious, and educational leaders that producing more food and fiber--or temporarily saving a few species of birds, animals, fish, insects, or plants from extinction in the name of protecting the environment--can, at best, be only a holding operation while the human population monster is being tamed.

Too often in the past, political and religious leaders and the general public have seen the dire predictions of Malthus and others of worsening food shortages and famine fail to materialize, and as a result, they have increasingly tended to ignore such predictions. Many fail to realize that in most recent cases, the development of new agricultural technology and its widespread application have only temporarily delayed the arrival of the predicted massive-scale disaster by increasing the carrying capacity of the earth for humans (often at the expense of other species). Others put

undeserved trust in science and technology, believing that they can continue indefinitely to develop new methods for expanding food and fiber production (and other essentials) and thereby continue increasing the standard of living of an infinite number of humans. Such belief is ill-founded and sets us on a collision course with Mother Nature. Nowhere is the human population monster more frightening than in Sub-Saharan Africa.

Over the next decade, investments in agriculture, rural education, primary health care, and community development--and the effectiveness of those investments--must be dramatically increased if we are to succeed in reversing Sub-Saharan Africa's current trends of declining per capita food production, worsening poverty, and environmental degradation. Organizations such as the World Bank and IMF wield tremendous power over the course of future development in these debt-ridden developing nations. There are no magic solutions. The development road ahead will be difficult to navigate. Never forget that the organizational models and policies recommended to and/or imposed upon the nations and people of Sub-Saharan Africa are far more than just "experiments." Although potentially beneficial, the present policies of "privatization" and "structural adjustment" followed in Ghana and other African countries can only succeed in the long run if short-run critical basic human needs are also met.

Are those in international agricultural development up to the challenges and responsibilities that confront them? The lives of millions of innocent people and of future generations hang in the balance.

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**CONSTRAINTS ON SUSTAINABLE
GROWTH IN AGRICULTURAL PRODUCTION:
INTO THE 21ST CENTURY**

Vernon W. Ruttan

The closing years of the 20th century complete one of the most remarkable transitions in the history of agriculture. Prior to this century almost all increases in food production were obtained by bringing new land into production. There were only a few exceptions to this generalization--in limited areas of East Asia, the Middle East, and Western Europe (Hayami and Ruttan 1985).

By the first decade of the next century, almost all increases in world food production must come from higher yields--from increased output per hectare. In most of the world the transition from a resource-based to a science-based system of agriculture is occurring within a single century. In a few countries this transition began in the 19th century. For most of the currently developed countries, though, it did not begin until the first half of this century. Most developing countries have been caught up in the transition only since mid-century. Among developing countries those of East, Southeast, and South Asia have progressed further in this transition than most countries in Latin America or Africa (Ruttan 1987).

This paper summarizes the conclusions from a series of three consultations or dialogues that were organized with leading agricultural, environmental, and health scientists to explore the constraints on sustainable growth in agricultural production into the first decades of the 21st century. It explores a number of agricultural, resource, environmental, and health concerns that will affect the capacity of the agricultural sector to respond to the demands that population and income growth place on the sector--particularly in the developing countries of Latin America, Asia, and Africa.¹

Introduction

The historical trends in production and consumption of the major food grains could easily be interpreted to mean one should not be excessively concerned about the capacity of the world's farmers to meet future food demands. World wheat prices, corrected for inflation, have declined since the middle of the last century, and rice prices have declined since the middle of this century. These trends suggest that productivity growth has been able to more than compensate for the rapid growth in demand, particularly during the decades since World War II.

As we look toward the future, however, the sources of productivity growth are not as apparent as they were a quarter century ago. The demands that the developing economies will place on their agricultural producers from population growth and growth in per capita consumption arising out of higher income will be high. Population growth rates are expected to decline substantially in most countries during the first quarter of the next century. The absolute increases in population size, however, will be large, and increases in per capita incomes will add substantially to food demand. The effect of growth in per capita income will be more rapid growth in demand for

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animal proteins and for maize and other feed crops. During the next several decades growth in food and feed demand arising from growth in population and income will run upwards of 4 percent per year in many countries. Food demand will double in many places before the end of the second decade of the next century.

Biological and Technical Constraints on Crop and Animal Production

Gains in agricultural production required over the next quarter century will be achieved with much greater difficulty than in the immediate past. It is currently difficult to raise yield ceilings for cereal crops that have experienced rapid yield gains in the past. The incremental response to increases in fertilizer use has declined. Expansion of irrigated areas has become more costly. Maintenance research, required to prevent yields from declining, is growing as a share of research effort (Plucknett and Smith 1986). The institutional capacity to respond to these concerns is limited, even in countries with the most effective national research and extension systems. Indeed, there was considerable difficulty in many countries during the 1980s in maintaining the agricultural research capacity that had been established during the 1960s and 1970s (Cummings 1989). It is possible that within another decade, advances in basic knowledge will create new opportunities for advancing agricultural technology that will reverse the urgency of some of the above concerns. Institutionalization of private sector agricultural research capacity in some developing countries is beginning to complement public sector capacity (Pray 1983). Advances in molecular biology and genetic engineering are occurring rapidly. But the date by which these promising advances will be translated into productive technology seems to be receding.

The following general conclusions are from the first consultation on biological and technical constraints on crop and animal productivity (Ruttan 1989).

Advances in conventional technology will remain the primary source of growth in crop and animal production over the next quarter century. Almost all increases in agricultural production over the next several decades must continue to come from further intensification of agricultural production on land that is presently devoted to crop and livestock production. Until well into the second decade of the next century, the necessary gains in crop and animal productivity will be generated by improvements from conventional plant and animal breeding and from more intensive and efficient use of technical inputs, including chemical fertilizers, pest control chemicals, and more effective animal nutrition.

The productivity gains from conventional sources are likely to come in smaller increments. Success will require higher plant populations per unit area, new tillage practices, improved pest and disease control, more precise application of plant nutrients, and advances in soil and water management. Gains from these sources will be crop-, animal-, and location-specific. They will require greater articulation between the suppliers and users of new knowledge and new technology. These sources of yield gains are extremely knowledge- and information-intensive. To ensure their success, research and technology transfer efforts in the areas of information and management technology must become increasingly important sources of growth in crop and animal productivity.

Advances in conventional technology will be inadequate to sustain the demands that will be placed on agriculture into the second decade of the next century and beyond. Advances in crop yields have come about primarily by increasing the ratio of grain to straw rather than by increasing total dry matter production. Advances in animal feed efficiency have come by decreasing the proportion of feed consumed that is devoted to animal maintenance and increasing the proportion used to produce usable animal products. There are severe physiological constraints to continued improvement along these

conventional paths. These constraints are most severe in those areas that have already achieved the highest levels of productivity: Western Europe, North America, and parts of East Asia. The impact of these constraints can be measured in terms of declining incremental response to energy inputs--in the form of both a reduction in the incremental yield increases from higher levels of fertilizer application and a reduction in the incremental savings in labor inputs from the use of larger and more powerful mechanical equipment. If the incremental returns to agricultural research also decline, it will impose a higher priority on efficiency in the organization of research and on the allocation of research resources.

A reorientation of organizing agricultural research will be necessary to realize the opportunities for technical change arising from advances in microbiology and biochemistry. Advances in basic science, particularly in molecular biology and biochemistry, continue to open up new possibilities for supplementing traditional sources of plant and animal productivity growth. A wide range of possibilities was discussed at the consultation, ranging from the transfer of growth hormones into fish to conversion of lignocellulose into edible plant and animal products. The realization of these possibilities will require a reorganization of agricultural research systems. An increasing share of the new knowledge generated by research will reach producers in the form of proprietary products or services. Incentives must therefore be created to draw substantially more private sector resources into agricultural research. Within the public sector, research organizations will have to increasingly move from a "little science" to a "big science" mode. Examples include the Rockefeller Foundation-sponsored collaborative research program on the biotechnology of rice and the University of Minnesota program on the biotechnology of maize. In the absence of more focused research efforts, the promised gains in agricultural productivity from biotechnology will continue to recede.

Efforts to institutionalize agricultural research capacity in developing countries must be intensified. Crop and animal productivity levels in most developing countries remain well below the levels that are potentially feasible. Access to the conventional sources of productivity growth, from advances in plant breeding, agronomy, and soil and water management, will require the institutionalization of substantial agricultural research capacity for each crop or animal species of economic significance in each agroclimatic region. In a large number of developing countries this capacity is just beginning to be established. A number of countries that experienced substantial growth in capacity during the 1960s and 1970s experienced an erosion of capacity in the 1980s. Even a relatively small country, producing a limited range of commodities under a limited range of agroclimatic conditions, will require a cadre of 250 to 300 agricultural scientists. Countries that do not acquire adequate agricultural research capacity will not be able to meet the demands placed on farmers as a result of growth in population and income.

There are substantial possibilities for developing sustainable agricultural production systems in a number of fragile resource areas. Research under way in the tropical rain forest areas of Latin America and in the semiarid tropics of Africa and Asia suggest the possibility of developing sustainable agricultural systems with substantially enhanced productivity even in unfavorable environments. It is unlikely, and perhaps undesirable, that all of these areas will become important components of the global food supply system. But enhanced productivity is important to those who reside in these areas--now and in the future. The research investment in the areas of soil and water management and in farming systems must be intensified in these areas.

There is a need for the establishment of substantial basic biological research and training capacity in the tropical developing countries. There are a series of basic biological research agendas important for applied research and technology development for agriculture in the tropics

that receive--and are likely to continue to receive--inadequate attention in the temperate region developed countries. There is also a need for greater cooperation between training in applied science and technology and training in basic biology. When such institutes are established, they will need to be more closely linked with existing academic centers of research and training than the series of agricultural research institutes established by the Rockefeller and Ford Foundations and the Consultative Group on International Agricultural Research (CGIAR).

Resource and Environmental Constraints on Sustainable Growth

There is growing concern about the impact of a series of resource and environmental constraints on the growth (2 to 4 percent a year) of agricultural production that will be required in most developing countries. A second consultation on issues of resource and environmental constraints on agricultural production was held in late November 1989 and included agricultural scientists, economists, and scientists involved in climate change studies.

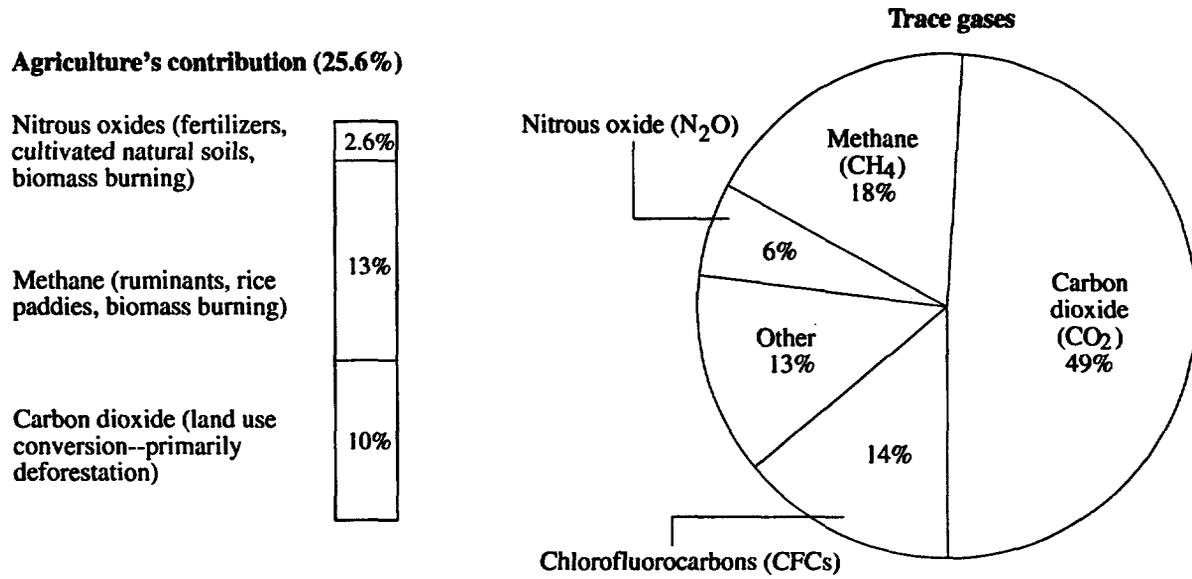
One set of concerns explored during the consultation focused on the impact of agricultural production practices that will be employed in those areas making the most progress in moving toward highly intensive systems of agriculture production. These include loss of soil resources due to erosion; water-logging and salinization; groundwater contamination from plant nutrients and pesticides; and growing resistance of insects, weeds, and pathogens to present methods of control. If agriculture is forced to continue to expand into more fragile environments, such problems as soil erosion and desertification can be expected to become more severe. Additional deforestation will intensify problems of soil loss and degradation of water quality and contribute to climate change.

A second set of concerns stems from the impact of industrialization on global climate and other environmental changes (Reilly and Bucklin 1989). The accumulation of carbon dioxide (CO₂) and other greenhouse gases--principally methane (CH₄), nitrous oxide (N₂O), and chlorofluorocarbons (CFCs)--has set in motion a process that will result in an increase in global average surface temperatures over the next 30 to 60 years. And there continues to be great uncertainty about the climate changes that can be expected to occur at any particular future date or location. It is almost certain, however, that the climate changes will be accompanied by rises in the sea level and that these rises will impinge particularly heavily on island Southeast Asia and the greater river deltas of the region. Drier and more erratic climate regimes can be expected in interior South Asia and North America. As a partial offset some analysts have suggested that higher CO₂ levels may have a positive effect on yield (Rosenberg 1986).

The bulk of CO₂ emissions comes from fossil fuel consumption. Carbon dioxide accounts for roughly half of radiative forcing. Biomass burning, cultivated soils, natural soils, and fertilizers account for close to half of nitrous oxide emissions. Most of the known sources of methane are products of agricultural activities: principally, enteric fermentation in ruminant animals, release of methane from rice production and other cultivated wetlands, and biomass burning. Estimates of nitrous oxide and methane sources have a very fragile empirical base. Nevertheless, agriculture and related land use could account for about 25 percent of radiative forcing (figure 1).

The alternative policy approaches to the threat of global warming can be characterized as preventionist or adaptionist. A preventionist approach could involve five policy options: (1) reduction in fossil fuel use or capture of CO₂ emissions at the point of fossil fuel combustion, (2) reduction in the intensity of agricultural production, (3) reduction of biomass burning, (4) expansion of biomass production, and (5) energy conservation. Of these, only energy efficiency and conservation are likely to make any significant contribution over the next generation. And the speed

Figure 1. Contributions to Increases in Radiative Forcing in the 1990s



Note: Radiative forcing measures the contribution to surface temperature change by the several greenhouse gases on the basis of their radiative properties.

Source: Reilly and Bucklin 1989.

with which either will occur will be limited by the pace of capital replacement. Any hope of significant reversal of agricultural intensification, reduction in biomass burning, or increase in biomass absorption is unlikely to be realized within the next several decades. The institutional infrastructure or resources that would be required do not exist and will not be in place rapidly enough. We will not be able to rely on a technological solution to the global warming problem. (Solutions, whether driven by preventionist or adaptationist strategies, must be both technological and institutional.)

An adaptationist approach should be adopted (though reluctantly) in attempting to assess the implications of global climate change for future agricultural research agendas. It implies moving as rapidly as possible to design and implement the institutions needed to remove the constraints that intensification of agricultural production is currently imposing on sustainable increases in agricultural production. Examples of current constraints include (1) commodity policies--such as those of the United States, the EEC countries, and Japan--that encourage excessive use of chemical inputs as substitutes for land; and (2) resource policies, such as those that inhibit the rational conservation, allocation, and use of surface and groundwater. Success in designing the policies and institutions needed to deal with existing resource constraints and management will allow a better response to the more uncertain changes resulting from future global climate change.

In the following section some of the research implications that emerged from the second consultation are discussed.

A major research program on incentive-compatible institutional design should be initiated. The first research priority is to initiate a large-scale research program on designing institutions capable of implementing incentive-compatible resource management policies and programs. Incentive-compatible institutions are capable of achieving compatibility among individual, organizational, and social objectives in resource management. A major source of global warming and environmental pollution is the direct result of the operation of institutions that induce harmful individual behavior and of public agencies that are not compatible with societal development--some might say survival--goals. In the absence of more efficient incentive-compatible institutional design, the transaction costs involved in ad hoc approaches are likely to be enormous.

A serious effort to develop alternative land use, farming systems, and food systems scenarios for the 21st century should be undertaken. A clearer picture of the demands that are likely to be placed on agriculture over the next century and of the ways in which agricultural systems might be able to meet such demands has yet to be produced. World population could rise from the present 5 billion level to between 10 and 20 billion. The demands that will be placed on agriculture will also depend on the rate of growth of income, particularly in the poor countries where consumers spend a relatively large share of income growth on subsistence (food, clothing, and shelter). The resources and technology that will be used to increase agricultural production by a multiple of three to six will depend on both the constraints on resource availability that are likely to emerge and the rate of advance in knowledge.

Advances in knowledge can permit the substitution of more abundance for increasingly scarce resources and reduce the resource constraints on commodity production. Past studies of potential climate change effects on agriculture have given insufficient attention to adaptive change in nonclimate parameters. But application of advances in biological and chemical technology, which substitutes knowledge for land, and advances in mechanical and engineering technology, which substitutes knowledge for labor, has been driven by increasingly favorable access to energy resources, i.e., declining prices of energy. There will be strong incentive, by the early decades of the next century, to improve energy efficiency in agricultural production and

utilization. Particular attention should be given to alternative and competing uses of land. Land use conversion, from forest to agriculture, is presently contributing to radiative forcing through release of CO₂ and methane into the atmosphere. Conversion of low-intensity agricultural systems to forest has been proposed as a method of absorbing CO₂. There will also be increasing demands on land use for watershed protection and biomass energy production.

The capacity to monitor the agricultural sources and impacts of environmental change should be strengthened. Only in the last 15 years has it been possible to estimate the magnitude and productivity effects of soil loss, even in the United States. Even rudimentary data on soil loss are almost completely unavailable in most developing countries, as are data on groundwater pollution, salinization, and species loss. Data on the effects of environmental change on the health of individuals and communities are even less adequate. It is time to design the elements of a comprehensive, agriculturally related resource-monitoring system and to establish priorities for implementation.

Lack of firm knowledge about the contribution of agricultural practices to the methane and nitrous oxide sources of greenhouse forcing was mentioned several times during the consultation. Much closer collaboration among production-oriented agricultural scientists, ecologically trained biological scientists, and the physical scientists that have been traditionally concerned with global climate change is essential. This effort should be explicitly linked with the monitoring effects currently being pursued under the auspices of the International Geosphere-Biosphere Programs (IGBP).

The design of technologies and institutions to achieve more efficient management of surface and groundwater resources will become increasingly important. During the next century water resources will become an increasingly serious constraint on agricultural production, a major contributor to the decline in the quality of both surface and groundwater. Limited access to clean and uncontaminated water supply is a major source of disease and poor health in many parts of the developing world and in the centrally planned economies. Global climate change will have an important differential impact on water availability and demand, erosion, salinization, and flooding. The development and introduction of technologies and management systems that enhance water use efficiency are a high priority, because of both short- and medium-term constraints on water availability and the longer-run possibility of seasonal and geographical shifts in water availability. The identification, breeding, and introduction of water-efficient crops for dryland and saline environments are potentially important aspects of achieving greater water use efficiency.

Research on environmentally compatible farming systems should be intensified. In agriculture, as in the energy field, there are a number of technical and institutional innovations that could have both economic and environmental benefits. Among the technical possibilities is the design of new "third"- or "fourth"-generation chemical, biorational, and biological pest management technologies. Another is the design of land use technologies and institutions that will contribute to reduction of erosion, salinization, and groundwater pollution.

Immediate efforts should be made to reform agricultural commodity and income support policies. In both developed and developing countries producers' decisions on land management, farming systems, and use of technical inputs (such as fertilizers and pesticides) are influenced by government interventions such as price supports and subsidies, programs to promote or limit production, and tax incentives and penalties. It is increasingly important that such interventions be designed taking into account the environmental consequences of decisions by involved landowners and producers.

A food system perspective should become an organizing principle for improvements in the performance of existing systems and for the design of new systems. The agricultural science community should be prepared, by the second quarter of the next century, to contribute to the design of alternative food systems. Many of these alternatives will include the use of plants other than the grain crops that now account for a major share of world feed and food production. Some alternatives will involve radical changes in food sources. Rogoff and Rawlins have described one such system based on lignocellulose--both for animal feed and human consumption (Rogoff and Rawlins 1987).

Health Constraints on Agricultural Development

The topic of the third consultation, held in June 1990, focused on health constraints on agricultural development. Why was this topic included in the series of consultations? Since the mid-1960s a number of commonly used health indicators such as life expectancy and infant mortality experienced substantial improvement for almost all developing countries. Concerns about nutritional deficiency as a source of poor health have receded in a large number of developing countries in the last several decades (BOSTID/IOM 1987; Commission on Health Research for Development 1990).

Yet there are a number of other indicators that suggest that health constraints could become increasingly important by the early decades of the next century. Daily calorie intake per capita has been declining for as much as two decades in a number of African countries. Although dramatic progress has been made in the control and reduction of losses resulting from infectious disease and in the control of diarrheal disease, there has been little progress in the control of several important parasitic diseases. The sustainability of advances in malaria and tuberculosis control is causing serious concern. The emergence of AIDS, combined with other health threats, could pose a major threat to economic viability in both developed and developing countries.

There is also a second set of health concerns arising out of the environmental consequences of the intensification of agricultural and industrial production that were discussed in the third consultation. As the environmental impacts of agricultural and industrial intensification become clearer, they are already imposing significant health burdens in some countries, particularly in parts of the U.S.S.R. and Eastern Europe, and may become more burdensome in the future.

If one visualizes a number of these health threats emerging simultaneously in a number of countries it is not too difficult to construct a scenario in which there are large numbers of sick people in many villages around the world. The numbers could become large enough to become a serious constraint on food production capacity. These concerns guided the dialogue in the third consultation.

Issues and Priorities for the 21st Century

Answers to the question raised at the beginning of the consultation--Does health represent a serious constraint on agricultural development?--are at best ambiguous. Scattered data from countries such as India, Indonesia, and Côte d'Ivoire indicate loss of days worked because of sickness in the 5 to 15 percent range. In the U.S.S.R. and Poland substantial numbers of work days are lost because of respiratory disease associated with atmospheric pollution.

There have been major "plagues" in the past that resulted in mortality levels sufficient to seriously impinge on food supply. In the 15th century following the Spanish conquest the Amerindian population in the basin of Mexico declined by about 90 percent. Most of the decline was the result of a series of epidemics: smallpox, measles, typhus, and plague. Famine,

associated with the high dependency to working adult ratio (the ratio of the old and young relative to workers in the more productive age groups), probably accounted for 10 to 15 percent of the population loss.

The population loss from most historical plagues in Europe and Asia was concentrated in the younger and oldest age groups rather than among the adult population of working age. Many adults had survived earlier attacks and had acquired some degree of immunity. The incidence of death from the European and Asian diseases introduced into the Americas was spread more evenly across age distribution because everyone was equally susceptible. The AIDS epidemic is unique in that it is killing people primarily at their most productive age. The result will be an increase in the dependency ratio. Important questions remain regarding the relationships between AIDS and other diseases: one apparent consequence of AIDS in East Africa is a rise in tuberculosis.

The World Health Organization actively cooperates with African and other high-incidence AIDS countries in estimating HIV infection and AIDS incidences. A further step should be to model the direct and interaction effects of the simultaneous incidence of HIV infection and tropical parasitic and viral diseases on morbidity and on mortality.

Specific Issues

The capacity to design systems of health delivery capable of reducing the incidence of illness continues to elude health policy and planning agencies in both developed and developing countries. Current systems in most countries can be more accurately described as sickness recovery systems than health systems. A major deficiency is the lack of a system for providing families and individuals with the knowledge needed to achieve better health with less reliance on the health care system. The point was made several times during the consultation that almost all countries have been able to design reasonably effective agricultural extension or technology transfer systems to provide farm people with the knowledge about resources and technology needed to achieve higher levels of productivity. We have yet to design an effective system to provide families and individuals with the knowledge in the areas of human biology, nutrition, and health practice that will enable them to lead more healthy lives.

The residuals produced as a by-product of industrial and agricultural production have become an even increasingly important source of illness in a number of countries and regions. The most serious impacts are occurring in the centrally planned economies of Eastern Europe, the U.S.S.R., and China. Increasing levels of atmospheric, water, and soil pollution have resulted in higher mortality rates and reduced life expectancies. The effects are seen in the form of congenital malformation, pulmonary malfunction, and excessive heavy metals in soils and crops grown on contaminated soils. Many of the health effects of agricultural and industrial intensification result from inadequate investment in the technology needed to control or manage contaminants. Rapid industrial growth in poor countries, in which investment resources are severely limited, will continue to be accompanied by underinvestment in the technology needed to limit the release of contaminants. The situation in Eastern Europe presents a vision of the future for many newly industrializing countries unless better technology is made available and more effective management of environmental spillover effects implemented.

Lack of location- or site-specific research capacity represents a major constraint on the capability of health systems in most developing countries. It is no longer possible to maintain the position that health-related research results can simply be transferred from developed country research laboratories or pharmaceuticals to practice in developing countries. Local capacity is needed for the identification and analyses of the sources of health problems. It is also needed for the analysis, design, and testing of health delivery systems. In the tropics the international donor community has

been much slower in supporting the development of health research systems than agricultural research systems. For example, there is now a network of more than a dozen international agricultural research centers (IARCs), sponsored by the Consultative Group on International Agricultural Research, that play an important role in backstopping national agricultural research efforts.

The only comparable internationally supported center in the field of health is the Diarrheal Research Center in Bangladesh. Furthermore, the capacity to conduct research on tropical infectious and parasitic diseases that was supported by the former colonial countries--the United Kingdom, France, the Netherlands, and Belgium--has been allowed to atrophy.

High birthrates are both a consequence and a cause of poor health. The demographic transition--from high to low birthrates--has in the past usually followed an increase in child survival rates. This suggests that improvements in health, particularly of mothers and children, are a prerequisite for decline in population growth rates. But high population growth rates, especially in areas of high population density, are often associated with dietary deficiencies that contribute to poor health and high infant mortality rates.

How to achieve high levels of health and low birthrates at low cost in poor societies remains unresolved. Several very-low-income countries have achieved relatively high levels of health--as measured by low infant mortality rates and high life expectancy rates--but often at a high cost relative to per capita income. Other societies that have achieved relatively high incomes continue to exhibit relatively high infant mortality rates and only moderately high life expectancy levels.

More effective bridges must be built, both in research and in practice, between the agricultural and health communities. At present these two "tribes," along with veterinary medicine and public health, occupy separate and often mutually hostile "island empires." But solutions to the problem of sustainable growth in agricultural production and improvement in the health of rural people and the consumers of agricultural commodities require each of these communities to establish bridgeheads in the other's territory. For example, multipurpose water resource development projects have contributed to the spread of onchocerciasis, but successful efforts to control the black fly have reopened productive lands to cultivation. The introduction of improved cultivars and fertilization practices has helped make the productivity growth sustainable. But examples of effective collaboration either in research or in project development are difficult to find.

Other Issues

Many of the problems discussed are international in scope. Many of the institutions that will be needed to enable societies to respond to the constraints on sustainable increases in agricultural production must involve international collaboration or transnational organizations. We can no longer get by with slogans such as "Think globally, act locally." We will have to institutionalize the capacity to respond to scientific, technical, resource, environmental, and health constraints. In the area of health, for example, almost every source of illness or poor health that exists in one place--whether an infectious organism or environmental change--will exist everywhere else. This statement may be an exaggeration, but only a slight one.

There is limited capacity to design the institutional infrastructure needed to sustain the required rates of growth in agricultural production into the first decades of the next century. We need to build institutional infrastructures that facilitate more effective collaboration among engineers, agronomists, and health scientists to deal with production, environmental change, and the health of food producers and consumers. The social science disciplines and related professions (law, management, social

service) have not demonstrated great capacity in the area of institutional design. Plant breeders have been much more effective. They do not simply analyze the sources of yield differences but utilize the agronomic and genetic knowledge that is obtained from their analyses to design improved cultivars-- plants and animals that are responsive to management and resistant to the assaults of nature. In the social sciences once we complete our analysis we feel that our job has been finished. We tend to stop at the level of analysis. We only rarely bring the knowledge we have acquired to bear on institutional design.

Increased attention must be given to the design of both technologies and institutions that will broaden our options for choice or action. Our discussion noted that the highest incidence of AIDS is likely to occur, at least during the next several decades, in those parts of the world where the technologies and institutions needed to sustain food production are exceedingly weak. Wider technical options will be needed in both food production and utilization.

There is inadequate capacity to monitor changes in the sources of productivity and environmental changes and the insults to health. We know very little about either the levels or the trajectories. We talk about soil erosion but do not have the monitoring capacity to know the extent to which it is weakening our capacity to produce. We are fighting a defensive battle against the health effects of the contamination of our food supply rather than anticipating the sources. One of the puzzling aspects of the data available so far is that the health effects of increased use of fertilizer is less than expected despite high levels of nitrate in surface and groundwater. Neither the developed nor developing countries have in place adequate surveillance systems for disease.

Perspective

The outlook for agricultural futures is cautiously optimistic. The challenges posed by the constraints on crop and animal productivity and by the resource, environmental, and health constraints on sustainability should not be interpreted as a completely pessimistic assessment. The global agricultural research system, the technology supply industry, and farmers are much better equipped to confront the challenges of the future than they were when confronted with the food crises of the past.

It cannot be emphasized too strongly, however, that the challenges are both technical and institutional. The great institutional innovation of the 19th century was "the invention of the method of invention." The modern industrial research laboratory, the agricultural experiment station, and the research university were a product of this institutional innovation. But it was not until well after the mid-20th century that national and international agricultural research institutions became firmly established in most developing countries. The challenge to institutional innovation in the next century will be to design the institutions that can alleviate the negative spillover into the soil, the water, and the atmosphere of the residuals from agricultural and industrial intensification.

The capacity to achieve sustainable growth in agricultural production and income will also depend on the changes that occur in the economic environment in which developing country farmers find themselves. The most favorable economic environment for releasing the constraints on crop and animal productivity and for achieving sustainable adaptation to the resource and environmental constraints that will impinge on Asian agriculture is one characterized by slow growth of population and by rapid growth of income and employment in the nonagricultural sector. Failure to achieve sustainable growth in the nonfarm sector could place developing country farmers in a situation in which they can make adequate food and fiber available to the nonfarm sector only at increasing prices--reversing the long-term trend--but

in which the resources available to generate the investments in resource and technology development necessary to sustain growth are inadequate.

Favorable growth in the nonfarm economy is particularly important for the landless and near landless workers in the rainfed upland areas that have been left behind by the advances associated with the seed-fertilizer-water technology of the last quarter century. Rapid growth in demand arising from higher incomes, rather than from rapid population growth, can generate patterns of demand that permit farmers in these areas to diversify out of staple cereal production and into higher value crop and animal products. It may also permit the release of some of the more fragile lands from crop production to less intensive forms of land use.

Notes

1. An earlier draft of this paper was presented at the Symposium on Population-Environment Dynamics, October 1-3, 1990, University of Michigan, Ann Arbor.

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SESSION II:
TECHNOLOGY FOR THE 1990S

**TECHNOLOGY FOR THE 1990S:
RATE AND POTENTIAL LIMITATIONS
OF TECHNOLOGY GENERATION**

Donald Duvick

Although the assigned title of this paper suggests broad possibilities, the paper will concentrate on technology advancement of major field crops, drawn, for the most part, from experience in maize breeding and culture in the northern hemisphere. It will also touch on U.S. advances in breeding and culture of wheat, soybean, grain sorghum, and cotton. Finally, it will speculate on possible advances in technology generation for breeding and culture of field crops in the tropics and subtropics, again drawing largely on experience in breeding and sale of those crops in various third world countries.

Hybrid Maize in the United States, 1930 to 1990

The Historical Record

Maize yields in the United States were static from 1900 to 1930. Then, coincident with the introduction of hybrid maize and mechanical corn harvesters in the U.S. corn belt, yields began to rise at an average annual rate of 57 kg/ha/yr (about 3 percent/yr, on average). This rate was maintained during the period 1930-55.

Around 1955, coincident with a sharp increase in rates of application of commercial fertilizers (nitrogen, in particular), the average rate of increase in maize yields rose again, averaging 144 kg/ha/yr during the period 1955-80. But because average yields also rose, the average increase per year as a percent of the 25-year mean remained at about 3 percent.

Fertilizer usage in the United States leveled off around 1980, and although U.S. maize yields may continue their upward trend, the rate of increase during the next 25-year period probably will be lower than that for 1955-80.

Causes of Yield Gains

What are the causes of this 60-year trend of increasing maize yields in the United States? A combination of continually improved cultural practices plus continually improved hybrids has been the main factor. Fluctuations in area planted to maize, with consequent additions or subtractions of less productive growing areas, have no doubt affected the annual averages, but not in any consistent way.

Major nonhybrid changes in maize production technology have been in weed control; fertilizer amounts and kinds; water control (in irrigated production areas, such as Nebraska); insect control (of corn root worm, in particular); and in planting, cultivating, and harvesting machinery.

Studies in the U.S. corn belt, for example, in Iowa, indicate that about half of the yield gains have come from improvements in corn cultural practices and the other half from changes in hybrid genotypes. Interactions between genetic and cultural changes (for example, newer hybrids are better

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adapted to increased plant densities) complicate interpretation of the changes over time.

Constraints to Further Progress

There is little likelihood of great yield improvement from further changes in most cultural practices, unless some unforeseen new practices are implemented. As noted, fertilizer rates have plateaued. They may even be reduced in years to come because of pressure for improvement of groundwater quality. Insecticide and herbicide use also is at near-maximum coverage and effectiveness. In addition, the use of these chemicals may decrease in the future because of environmental considerations.

Machinery for tillage operations is being modified annually, but goals are to change tillage practices in ways that prevent soil erosion while simply maintaining yields. Machinery for planting and fertilizing eventually will be computer-controlled to permit on-the-go changes in fertilizer application and planting rates. This will allow adjustment to in-field variations in soil type. These changes, however, will essentially be intended to reduce input application while holding yields constant, as well as possible.

Harvesting equipment probably will continue to provide annual marginal improvements in grain-saving ability, but combines already waste very little grain in the harvesting operation.

The human factor probably provides more opportunity than any other nonseed input for further changes that will increase yields per hectare. Although U.S. maize farmers as a class are sophisticated and efficient, there are still a significant number of marginally efficient maize farmers. Such farmers tend to be (a) part-time, (b) over-extended and large-scale, or (c) found in areas where maize is a marginal crop, as in the southeastern United States.

There is no quantification of the proportion of U.S. maize production that is dependent on this class of farmers, but their production can be estimated at not more than 5 to 10 percent of the total tonnage. Raising this less-efficient class to optimal efficiency, therefore, cannot contribute a great deal to increases in maize yields, and of course it would only be a one-time improvement.

Thus, improvements in yielding ability, that is, improvements in hybrid genotypes, will be an increasingly important part of the technology needed to keep U.S. maize yields on an upward trend, for genetic improvement is the only input that has not yet reached its potential.

But what are the possibilities for such continued genetic improvement? And, if genetic improvements are possible, in what traits will they be found?

Sixty Years of Genetic Improvement

Study of past changes may help in predicting future changes. Several studies (most of them conducted in Iowa) have shown that genetic yielding ability has increased continually and uniformly since 1930, at rates of about 70-90 kg/ha/yr, equivalent to an average gain of 1.5 percent/yr (average annual gain divided by mean of test x 100). All studies indicate that gains are still continuing; no plateau is in sight for increases in genetic yielding ability. But because gains are linear (in kg/ha), and average yields continue to increase, the annual percent of improvement is decreasing.

Analysis of performance traits indicates that hybrid yield gains are shown at both low and high plant densities (planting rates in the 1930s

were 1/2 to 1/3 as great as those in the 1980s); at low and high fertilizer rates; in severe as well as in light insect infestations (primarily of European corn borer and two species of corn root worm); in both severe and light disease conditions (primarily stalk rot and northern corn leaf blight); in severe drought as well as in well-watered years; and in abnormally hot or cool seasons as well as in seasons with normal temperature ranges.

In sum, maize hybrids through the years have been increasingly well buffered, genetically, against constraints to yield in the U.S. corn belt. They have stronger roots, better resistance to stalk rot as well as to other fungal and viral diseases, more tolerance of insect attack, greater resistance to heat/drought-induced barrenness, and greater resistance to heat/drought-induced premature death.

Equally important, the newer maize hybrids for the U.S. corn belt have greater ability to make the best of favorable growing conditions. Thus, new hybrids have their greatest absolute advantage (in kg/ha) over old hybrids in well-watered fields, equable growing seasons, well-fertilized fields, and seasons without extremely heavy disease or insect pressure.

Plant Morphology and Development

Interestingly, newer hybrids in the U.S. corn belt have approximately the same stature, leaf number and leaf area, and maturity ratings (both for flowering date and for grain moisture at harvest) as the old hybrids. These traits have not changed in directional fashion over the years. Nor has harvest index changed to any large degree. When the old hybrids are highly barren--in hot, dry years--the new hybrids have a significantly higher harvest index. But in high-yield years this advantage is not seen.

The new hybrids do have significantly higher weights of total above-ground dry matter. Both grain and leaves/stalks are heavier in the newer hybrids. In particular, the new hybrids have greater stalk density.

Increased biomass production, rather than improved harvest index, is the basis for greater grain yield of the newer hybrids. Significantly, the newer hybrids have a longer grain-fill period, probably because they are less prone to stress-induced premature death in the latter part of the growing season. Despite this longer period for kernel development, a more rapid dry-down of the maturing grain in the newer hybrids allows them to be ready for harvest as soon as the older hybrids. Thus, the new hybrids have more time for grain fill and yet have the same harvest maturity (the same grain moisture content at harvest time) as the old hybrids.

Stress Tolerance

U.S. maize hybrids, therefore, have shown increasingly improved performance under poor as well as good growing conditions. This dual improvement--in toughness as well as in ability to take extra advantage of optimal growing conditions--is not well known and indeed is often denied by those unfamiliar with the facts.

The confusion may be understandable. For example, new hybrids are better adapted to high plant densities and so can yield more per unit area than the older hybrids. Yields of old hybrids actually decline at high plant densities whereas new hybrids yield more. (Old hybrids often fail to develop ears at high densities. New hybrids are less likely to have this problem. They therefore make more ears per hectare at higher densities. Ear size of all hybrids is reduced at high densities; however, increase in ear numbers for the newer hybrids compensates for fewer kernels per ear, and the net result is more kernels per hectare.)

Plentiful water and fertilizer supplies increase the "old versus new" difference even more, especially at high densities. Erroneous

extrapolation may lead some to believe that the new hybrids do well only when such "luxury" conditions are present. In actuality, high densities, high soil fertility, and even plentiful water supplies add new constraints to yield, such as self-shading, poor root development, and encouragement of disease and insect problems. The new hybrids are able to cope with these constraints; the older ones cannot.

Yield Potential versus Yield Stability

Why have U.S. maize breeders improved both yield potential and yield stability in the same hybrids? What contribution have these simultaneous changes made to the 60-year upward trend in U.S. maize yields?

U.S. maize breeders, testing as they do in a wide range of growing conditions, have been constrained to save hybrids that yield well in both high-yield and low-yield conditions. Only these hybrids have the highest average yields. Furthermore, a continuing iteration occurs when the hybrids are released and grown commercially. Corn belt farmers rapidly reject hybrids that are not top-yielding in both high-yield and low-yield years, in presence or absence of disease and insect pressure, and in well-fertilized or poorly fertilized fields. They clearly state their objections to the companies that sold the hybrids. Breeders are necessarily sensitive to customer demand and do their best to provide hybrids that will not lose favor in any type of growing condition. (U.S. corn belt farms have, on average, much greater maize yield potentials and greater stability of yield than most areas in the tropics or subtropics. Nevertheless, the continental climate and the high prevalence of rainfed farms in the U.S. corn belt ensures wide swings in temperature and available moisture for its maize fields. Intensity of infestation of major insect pests--European corn borer and corn root worm--also is highly variable by season and by region. Maize yields consequently can vary severalfold among locations and years.)

Possibilities for Further Genetic Advance

When will it no longer be possible to make genetic improvements in yielding ability in U.S. maize hybrids? When will the yield ceiling be reached?

No hybrid is superior in all traits. Breeders will continue to improve genetic yielding ability in maize hybrids for many years to come. Superior germplasm is available for improving all traits, and effective breeding methods for combining various superior genotypes in one hybrid are on hand.

Incremental but significant improvements in hybrid yielding ability therefore will continue, as long as research and development is supported by the hybrid maize industry and fundamental research to undergird the industry work is provided by university and government institutions. The genetic improvements will be based on ability not only to make maximum yield but also to tolerate stress.

Stress tolerance traits most likely to be improved for advancement of hybrid yield are those that affect tolerance of heat/drought, European corn borer, corn root worm, and suboptimal levels of soil nitrogen. These constraints will be the most important ones in future years if predictions of climate change, as well as predictions of reductions in intensity of fertilizer and insecticide use, are correct. Ability of hybrids to tolerate these constraints, especially during short periods of stress, will give them maximal ability to express their genetic potential for high yield.

The cost of research per unit of advance, however, will become increasingly high. Over the past 60 years, increases in maize yielding ability at a rate of approximately 1.5 percent/yr have been accompanied by increases in numbers of U.S. maize breeders at a rate of about 4 percent/yr (at least in

one major U.S. seed company). Thus, yield gains, although still possible, are increasingly expensive; in other words, genetic gain per maize breeder per year decreases annually.

Genetic Contributions to Yield Gains in Grain Sorghum

Historical Events

U.S. grain sorghum yields took a sharp turn upward when hybrids were introduced in the late 1950s, similar to what happened for maize yields after the introduction of hybrid maize. Average yields for grain sorghum, however, have not continued on a steady upward trend.

The new grain sorghum hybrids were grown under unprecedented, large monocultural irrigated acreages, and beginning around 1970 they were subjected to heavy insect and disease pressures. The relatively narrow-based series of hybrids had little or no resistance to these new problems, and yields fell off until breeders could develop and deploy tolerant and/or resistant hybrids. This was done, and by about 1975 the insect and disease problems were under control.

Then, around 1975 the global energy shortage increased the cost of fuel for irrigation pumping, which in turn caused farmers to reduce the acreage devoted to producing grain sorghum under irrigation. Reducing the percentage of irrigated sorghum caused a second sharp reduction in average yields of U.S. grain sorghum. During this time, however, sorghum breeders increased the genetic yielding ability of sorghum hybrids within major categories such as adaptation to irrigation, dry land, short season, or high incidence of stalk rot.

Causes of Genetic Yield Gains

One study indicates that genetic yield gains in grain sorghum hybrids are associated with increases in total plant weight, leaf area, and kernels per panicle. Other studies show significant improvements in resistance to ovule abortion caused by heat stress before anthesis, as well as in resistance to premature death--with consequent loss in yield and standability--caused by heat stress during grain fill. (These improvements are identical to changes in U.S. maize hybrids, which as noted earlier have shown successive improvements in resistance to barrenness caused by heat and drought stress before anthesis, and in resistance to premature death caused by heat and drought during late grain fill.)

Thus, U.S. sorghum breeders, like U.S. maize breeders, have improved their crops' yield potential for both high-yield and low-yield conditions. Because sorghum typically is planted in less favorable climatic regions it has been somewhat more difficult to demonstrate the advantages. Nevertheless, one study indicates that from 1950 to 1980, about 35 to 50 percent of sorghum yield gains were the result of improvements in hybrid genotypes. Genetically controlled yield potential increased at rates of about 1.6 percent/yr, about the same as those for maize in the U.S. corn belt.

U.S. sorghum breeders believe that genetic yield gains will continue to be made for many years to come, based on their experience in continually turning out hybrids that can outyield their predecessors within each adaptation category.

Genetic Contributions to Yield Gain in U.S. Wheat

Historical Events

U.S. wheat yields, like those of maize, began to rise in about 1930, and then rose more steeply, on average, following increases in use of nitrogen fertilizer (and herbicides) in the 1950s. Rates of yield increase

were only half as great as those for maize--about 1.5 percent/yr, on average. Differentiation of U.S. wheats into several distinct classes precludes any very general statements about genetic gain in U.S. wheat varieties. Such statements must be qualified according to climatic and market/quality constraints. (For all classes of wheat, hybrids have made no contribution to gains in yield on the farm. Despite more than 20 years of breeding effort, it has not been possible to produce and sell hybrid wheat at prices that give a profit to the seed firms and also to the farmers.)

Genetic Yield Gains

In one survey, an average of trials involving all major classes of wheat gave an average genetic gain in yield of about 0.7 percent/yr for the period 1958-80. Gains were greatest in those areas with fewest environmental constraints. In some of the more stressful areas genetic progress appeared to be at a standstill.

More recent analyses have shown that genetic yield gains continued to be made throughout the 1980s in all major U.S. wheat growing areas, with no plateau in sight. As indicated in the earlier study, the greatest gains were in the most productive wheat-growing regions--those with the fewest environmental constraints.

Generally, genetic improvements have accounted for about 50 percent of total gains in yield. Improvements in harvest index resulting from utilization of the semidwarf trait have been a major cause of yield improvement, but yield gains were being made even before appearance of semidwarf breeding materials. Moreover, yield gains continue to be made within the semidwarf types. Genetic improvements in yielding ability, therefore, can be attributed not only to improvements in harvest index, but also to improvements in other traits.

For example, breeders (at least in southern growing regions) note improvements in ability to resist premature death resulting from heat/drought during grain fill (as in maize and sorghum). Other data indicate that the newer varieties not only have higher average yields, but they also have greater stability of yield--better tolerance of unspecified environmental constraints to yield. Breeders in most regions note improvements in straw strength within the semidwarf height classes.

Because yields are improving without further shortening of the plant (that is, new semidwarf varieties yield more than earlier semidwarf varieties), total dry matter production per unit land area must be increasing in U.S. wheats, but there are no data on this for U.S. wheats.

Maintenance Breeding

Disease outbreaks continue to complicate attempts to compare performance of new varieties with the older ones, but general breeder experience (at least in the hard red winter, hard red spring, and soft red winter classes) indicates that as with grain sorghum and maize, the new wheat varieties repeatedly outyield their predecessors even in the absence of diseases specific to the older varieties. No plateau is in sight. Maintenance breeding has not restrained progress in advancement of genetic yield potential of U.S. wheat varieties.

Contributions of Genetic Technology to Soybean Productivity

Historical Record

U.S. soybean yields since 1930 (when records began) differ from those for maize, sorghum, and wheat in that they show no change in average rate of increase over the years. The rate of increase since 1930 has averaged about 20 kg/ha/yr, an average increase of about 1 percent/yr. This consistent

rate of improvement does not seem unexpected. Soybeans are a legume and so were not directly affected by changes in nitrogen fertilizer usage. They have not been sold as a hybrid, and they have not been subjected to major plant type change. No large, stepwise changes in breeding or management have been made for soybeans since the 1920s. Changes have been made, but they were incremental and gradual.

Genetic Improvements in Yielding Ability

Genetic improvements in soybeans, as with other major U.S. crops, have been responsible for about 50 percent of the total gain in soybean yields. Considering the very narrow genetic base of U.S. soybean breeding, this is a remarkably good achievement.

Improvements that probably contribute to soybean yield potential are in standability and ability to set seed and avoid pod drop during stress periods. As with wheat, much effort is devoted to maintenance breeding, because of continual emergence of new biotypes of phytophthora root rot and cyst nematode. But yield gains continue to be made even by varieties with the new resistance genes. Progress also is being made in breeding for multifactorial tolerance (presumed to be more durable) as opposed to simply inherited resistance to nematode and phytophthora biotypes. As with wheat, there is increased evidence that the new varieties have greater stability of yield, within and between years.

Genetic Contributions to Yield Changes in Upland Cotton

Historical Events

Average U.S. lint yield in upland cotton remained the same, on average, for many years until about 1935. Yields then began an upward trend that continued until about 1960. But after 1960, average U.S. yields of upland cotton plateaued, or declined slightly. Nevertheless, trials have shown that genetic yield potential increased continuously from 1910 through 1980. The declines in on-farm lint yield per hectare are remarkable in that they occurred during a period when many technological improvements were introduced: fertilizer, mechanization, and pesticides, in addition to cultivars with higher yield potential.

Contributing Factors

Possible causes of the yield plateau are the negative effects of monoculture, herbicides, insecticides, reduced rates of insecticides, or new pest biotypes. None of these is unequivocally established as causative. The evidence suggests (according to one reviewer) that lint yields would be declining sharply if breeders were not countering the negative cultural effects with continually improved new varieties. Breeders find no evidence of a plateau in genetic yielding ability. New varieties continue to outyield their predecessors in side-by-side comparisons.

Cotton is nearly unique among U.S. field crops in that little or no genetic tolerance or resistance is available for some of the major insect pests and therefore little or no maintenance breeding has been done against them. However, breeders do select strongly for resistance to several disease organisms.

Technology Advances for Field Crops in the Tropics and Subtropics in Relation to Advances in Temperate Zones

Reduced Rates of Gain

There has been concern recently that production per unit area of rice and wheat in the developing countries is no longer increasing at rates achieved during the past 25 years, or has even plateaued or is declining. For

maize in developing countries, chief concerns are that rates of improvement in production per unit area have not yet approached those achieved in earlier years by rice and wheat.

Slow rates of gain for rice and wheat yields are the result, in part, of lack of progress in raising genetic yield potentials and in part of diminishing returns from application of inputs such as fertilizer and irrigation water. For maize, slow rates of improvement in yield levels are partially the result of limited use of improved genotypes and of meager application of other external inputs. Maize in many developing countries is grown as a second- or third-choice crop, or is grown by farmers in areas with many environmental constraints. In either case farmers are not inclined to use fertilizer, irrigation, and other inputs as freely as with rice or wheat. (In a few regions in the tropics and subtropics, however, maize is a favored crop, grown with plentiful inputs, and has shown relatively large rates of gain in production per unit area.)

The apparent lack of progress in raising genetic yield potentials in rice and wheat has been attributed to the preoccupation of breeders with "maintenance breeding," that is, with adding much needed genes for resistance to or tolerance of continually new biotypes of insect and/or disease organisms. Because of either unfavorable linkages with the resistance genes, or the inability of breeders to find new ways to raise genetic yield potentials, new varieties are not able to yield more (presumably) than the first breakthrough varieties, in absence of disease and insect constraints.

Genetic Yield Gains Still Possible

Maintenance breeding, however, need not and will not prevent breeders from raising the yielding ability of new varieties of rice and wheat. As breeding pools begin to fill with full assortments of new resistance genes, including some not yet needed, the general yielding ability of the germplasm can be raised, and new varieties with new assortments of yield-promoting genes will emerge, with needed disease and resistance genes already in place.

Particularly, when breeding pools are reinforced with genes for multifactorial, durable kinds of tolerance, as opposed to all-or-nothing single-gene resistance, breeders will be able to get on with their job of increasing productivity.¹

Pressures from insect and disease pests are much greater in the tropics and subtropics than in temperate zones, and therefore greater proportions of total effort will need to be devoted to selection for adequate levels of pest tolerance and resistance. But the principle remains the same in any part of the world: plant breeding can continue to raise genetic yield potentials while maintaining adequate levels of pest and stress tolerance. Indeed, to genetically improve such tolerances may be a primary way of raising achievable yield levels.

Maintenance Breeding in U.S. Crops

The first maize hybrids for the U.S. corn belt were initially successful throughout the entire corn belt. Because of this success, a very narrow base of genotypes covered the entire region by the end of the 1930s. Shortly thereafter (starting in the 1940s), northern corn leaf blight epidemics began to decimate hybrids in the eastern part of the corn belt.² Travelers commented on the "early frost" that affected mile after mile of maize fields; farmers complained about the low fodder value of their prematurely dead crop. Breeding programs were initially set back as breeders searched for resistance genes and began the difficult job of adapting blight-resistant germplasm (mostly from unadapted, lower-yielding varieties) to the eastern corn belt.

But within 10 years, the pool of elite breeding materials for the eastern corn belt was well supplied with blight-resistant stocks, based on multiple factor resistance. From that time on, all (or nearly all) new hybrids from the eastern corn belt automatically contained sufficient levels of tolerance to northern corn leaf blight. Breeders were able to concentrate on improving the hybrids for other performance traits, not the least of which was yield.

U.S. sorghum and soybean breeders had similar experiences, with greenbug epidemics (sorghum) and cyst nematode and phytophthora (soybeans). Sorghum breeders are dealing with the second race of greenbug, and soybean breeders have worked their way through as many as a half-dozen biotypes each of cyst and phytophthora. Wheat breeders also have gone through various biotypes of stem rust and Hessian fly, as well as other diseases, including several viruses. But breeders for all three crops continue to introduce varieties with greater yield potential, in presence or absence of the insect and disease problems.

Similar stories are probably on record for the high-yield rice and wheat varieties for developing countries. One account details nearly 20 years of maintenance breeding for leaf rust resistance in wheats for the Yaqui valley of northwest Mexico. Increasing diversity of resistance genes has kept the disease under control. At the same time, yield potentials have climbed continually, at an average rate of about 1 percent/yr. Yield gains are the result, not of improvements in harvest index, but of increases in grain numbers per unit area. Varieties tend to have a longer pre-anthesis phase and greater phytomass (reminiscent of yield-enhancing changes in U.S. maize hybrids).

But the continuing increases in yield potential of wheats for the Yaqui valley have not always been accompanied by continuing yield increases in farmers' fields. Early gains in on-farm yield (which were probably due to simultaneous, interactive changes in growing practices and variety genotype) plateaued in the late 1970s. In recent years, however, yields seem to have again started to rise.

During the period when on-farm yields were flat, either the newest improved cultivars were not widely used, or their superiority in breeders' tests could not be duplicated under farm conditions. Another possibility might be the one suggested to explain plateaued lint yields for U.S. upland cotton farms: advances in genetic yielding potential were balanced against declining productivity of the farmers' fields, just enough to prevent yield declines but not enough to actually raise yields.

U.S. Experience in Breeding for Maximum Yield Potential

Reports that the newest high-yield rice varieties yield no more than the first successful high-yield variety, in absence of pest constraints, are reminiscent of the first season's results of a yield trial that compared old and new maize hybrids in Iowa.

Hybrids in the test spanned the time period 1935-72. The first year of the trial was exceptionally stress-free. Trials were grown at three densities: low, medium, and high. The low density was typical of that of the 1930s; the other two represented those of the 1970s. Plants at the low density were very well grown and in that stress-free year had very few constraints to development. The regression line, plotting hybrid yield against year of hybrid introduction, was nearly flat.

In that first season's trial, there was no significant advantage in yield for the newer hybrids at the low density. Thirty-five years of maize breeding seemed to have been ineffective. At the medium and high densities, however, the newer hybrids made large advances in yield, whereas the older hybrids were reduced in yield. Regression calculations showed consistent and

significant improvements in yielding ability at medium and high densities, from oldest to newest hybrids.

Further testing in subsequent years showed that the newer hybrids were superior not only when stressed by high densities, but also when stressed by other soil, weather, and pest constraints. Stresses of some kind showed up every year, sometimes to a large degree, sometimes only slightly. Consequently, the regression calculations for data pooled over locations and years always showed consistent and significant rates of increase in yield per hectare, from oldest to newest hybrids. (This was true even when low density trials were used as the basis for yield of the oldest hybrids.)

Potential yield per plant in absence of environmental constraints had been raised very little over 40 years of maize breeding. But yielding ability of hybrids on a per hectare basis, and their ability to cope with severe constraints to yield, had been raised significantly and steadily through the years. Essentially, the new hybrids were able to consistently produce more kernels per hectare by overcoming constraints to kernel development caused by high plant densities, drought, pest attack, and other environmental challenges. The changes were similar to those related above for wheat in Mexico's Yaqui valley.

Of course, farmers were an important part of the yield equation. Through the years they had learned how to raise plant densities to match the capabilities of the hybrids and also how to modify soil fertility levels to match the hybrids' capability to respond. Indeed, farmers usually tried to stretch hybrid capability beyond its genetic potential, thereby stimulating breeders to make hybrids even more stress-resistant with even higher yield ceilings.

Necessity of Breeding for Stress Tolerance Plus High Yield Potential

Based on this experience, analogies may be drawn for breeding in the tropics and semitropics. For example, a ceiling seems to have been reached for rice varieties in stress-free growing conditions, i.e., with well-managed irrigation, adequate fertilizer, and in absence of disease and insect pressures. But such conditions are probably found only rarely in the rice farmers' production fields. Irrigation water timing, quality, and quantity are optimal for only a small proportion of growers.

If this is the case, most of the growers need rice varieties with ability to take the shocks of inadequate amounts, quality, or timing of water. Perhaps development of stress-tolerant rice varieties, and correct labeling of their degree and kinds of tolerance (to allow their proper deployment by farmers), will raise overall production levels even for irrigated rice. (Farmers near the end of branch irrigation canals might use varieties with more tolerance for late or insufficient watering, for example, thereby raising their average yields.) Similar types of targeted breeding might be done (and probably are being done) for rice varieties adapted to the different seasons (wet versus dry, hot versus cool) in each growing area.

The same kind of speculation might be helpful in designing programs for wheat variety development. Much breeding along these lines is no doubt already in progress for both rice and wheat; however, it would have started later than the first (relatively easy) cycle of breeding for optimal environments and so has not yet had time to provide large-scale results.

Breeding for all crops, in even "high-yield" regions, must include selection simultaneously for high yield potential (testing in relatively stress-free conditions) and for tolerance of environmental stresses (testing in those unfavorable weather or soil conditions most likely to be experienced by some of the farmers some of the time).

The proportionate intensity of selection for high yield potential can be varied in relation to the probability that near-perfect growing conditions will be available in the targeted area. Selection pressure for tolerance of and/or resistance to insect and disease pests will be adjusted according to expectations for specific pest problems in the targeted areas.

A second principle of breeding is that in the second cycle (i.e., after the first generation of breakthrough varieties has been developed), breeding will be more productive if it aims to produce varieties with more localized adaptation.

Although one of the great achievements of modern plant breeding is the development of varieties with a very broad range of adaptation, it is always possible to also breed in additional location- or season-specific adaptations, producing varieties with even greater potential for a reliably high level of performance. The second-cycle varieties will have broad adaptation because they are able to cope with many constraints of moderate severity, and they also will have location- or season-specific adaptation because they have a high degree of tolerance to the specific and often severe constraints of a particular environmental niche.

Of course, more plant breeding stations and more plant breeders are needed to breed for local adaptation. This fact must be understood and appreciated not only by plant breeders, but also by those who fund plant breeding. It will cost increasingly more to produce increasingly productive varieties. More farmer input and advice will be needed as well in breeding varieties for better local adaptation.

Interactions between Farmers and Plant Breeders

As noted earlier, U.S. maize farmers often goaded breeders into developing hybrids able to cope with new cultural practices, such as higher fertility levels, higher plant densities, adaptation to earlier planting, and adaptation to combine harvesting. There will certainly be opportunities for breeders in developing countries to also learn from the farmers and to adjust their breeding practices accordingly. In particular, the leading farmers in each target region may have important lessons for the breeders.

Such breeding for the needs of the leading farmers--those who are known to be the most productive with the means at their disposal--does not necessarily mean that relatively tender varieties requiring high and expensive inputs will be developed. The most productive and perceptive farmers are usually the first to complain about variety weaknesses and also the first to try--or to develop--cost-saving alternatives to expensive inputs, provided they lead to greater profit.

Also, to work with the leading farmers does not mean working only with those having the most land, or those whose land has the highest natural yield potential.³ Rather, the leading farmers should be chosen from targeted, specific production areas and/or economic classes. These people will be the most productive and willing participants with breeders, in a constructive, continuing two-way education.

This recommendation also will require establishment of more breeding stations, ones in which the breeders live and work with the surrounding farmers year-round. Only in this way can productive synergies be developed. On-site residence further ensures that the breeders can watch their breeding materials and performance trials during all stages of development, thereby gaining locale-relevant insights into the fine points of organ differentiation, pest cycles, and soil and water interactions with genotype. On-site residence also will provide a better opportunity for gaining familiarity with the fine points of farmer techniques for management of locale-specific constraints. Farmers can become part of the breeding process.

New Technologies for the 1990s

Knowledge-Intensive Farming

In the 1990s in many parts of the developing world, farmers will need to learn more about the principles of intensive yet sustainable farming practices. Farmers with such kinds of knowledge can make maximum profit from advanced varieties, and furthermore, they themselves will be able to add to the knowledge about making the new varieties fully profitable and productive.

Knowledge-intensive, even more than input-intensive, farming will be required if production is to be increased in the developing countries in the 1990s. Just as U.S. farmers in the 1980s had to move (with more or less success) beyond relatively simplistic high-input types of farming, so will third world farmers need to begin raising productivity per hectare by means other than added water, fertilizer, and pesticides.

Genotype x management interactions, manipulated with biological insights, will be the chief means of raising yield levels in sustainable ways in the 1990s. Breeders, agronomists, ecologists, and farmers will need to work as teams to accomplish this end. At some stages in the process, economists and sociologists also will be needed.

Perhaps in the 1990s raising yield levels per se will no longer be the goal. Perhaps the goal, defined within the concept of sustainable agriculture for developing countries, will be to raise profitability per hectare, with profit defined as units of human sustenance per unit of nonpolluting land/energy/water inputs. This would be an extremely complicated equation. It certainly would require integrated efforts from many specialties, under the guidance of, and in the end evaluated by, the first generalist--the farmer.

Hybrid Crops

Hybrid maize will take over increasingly large proportions of maize production areas in developing countries. First utilization will be where maize grain markets, and infrastructure for provision of production inputs, are in place.

The initial increases in yield resulting from controlled heterosis will be followed by further and continuing increases in yield resulting from successively more productive hybrid releases, coupled with wider-scale utilization of production practices that allow maximum yield expression. Farmer demand will pull breeders and investments in breeding toward development of continually more productive hybrids--if the market for maize grain continues to grow in a reasonably stable fashion.

Indigenous small private seed companies, utilizing inbred products of national and IARC breeding programs, will provide much of the impetus for growth of the hybrid seed business. Their entrepreneurial ingenuity will provide continuing ferment and new ideas for advance, particularly in unexploited market niches. Another important segment will be the international seed companies, most of them based in industrial countries but breeding, producing, and selling in the developing countries. They will provide global resources in funding and germplasm and an element of stability in germplasm improvement and breeding technology.

Hybrid rice will provide further yield increases in rice production, but only in limited areas because of cost of production of the hybrid seed. Odds are perhaps slightly more than even that this crop will be economically successful--that the cost of hybrid seed production will be low enough to allow seed prices to remain in an affordable range.

Hybrid wheat will not appear in the developing world in the 1990s because of costs of hybrid seed production in relation to value of the commodity.

Crucial Technologies for the 1990s

Other new technologies will begin to have impact in the 1990s, but the major effects--the most important results--will come from those already in place: plant breeding, the present bundle of knowledge-intensive farming practices, and the interactions now present between the farming and research communities. Nothing can be more important in the near term than to expand, fine-tune, and produce products--both material and intellectual--with these three technologies.

An additional and highly important factor, of course, is the web of complicated interactions among market, government, and transportation forces. To discuss these forces and interactions, however, is beyond the scope of this paper.

Biotechnology for the Next Century

Despite the importance of present technologies for progress in the next decade, the future of the developing world beyond the 1990s depends on sound development--during the 1990s--of the new wave of molecular and cell biology technologies, many of which are subsumed under the title of biotechnology. To properly utilize biotechnology will require a new pattern of behavior, expectations, and responsibilities for most developing countries.

Some of the new technologies, for example, those utilizing tissue culture techniques for making disease-free clonal progeny, are well suited to exploitation by developing countries. But most of the technologies involving molecular biology--restriction fragment length polymorphisms (RFLPs), genetic transformation, gene isolation and cloning, and even diagnostics--require large, centralized, technically sophisticated research facilities. To provide such facilities often will be beyond the reach of individual third world countries.

In addition, extensive interactions, collaborations, and materials exchanges occur among biotechnology laboratories. In many cases intellectual property rights (patents and similar kinds of protection) are involved, such that secrecy agreements, license arrangements, or reciprocity agreements are required before further work can be done. Most developing countries are not equipped, with laws, experienced personnel, or attitude, to engage in such activities.

To move into the 21st century in plant breeding, developing countries will need to join in international networks of collaborating field plant breeders, laboratory plant breeders (biotechnologists), and patent lawyers. New attitudes, laws, and legal skills will be required.

New Role for the IARCs

For a more efficient transition, assistance can be given by the plant-oriented international agricultural research centers (IARCs) through an extension of their present missions. They can become centers of excellence and/or knowledge in some of the most important aspects of molecular biology: RFLP technology and application, cell and tissue culture, and genetic transformation. They need not be fully sufficient in these areas--no laboratory can be--but they should be proficient enough that their scientists can stay in touch with cutting-edge technology and practitioners.

They then can become intermediaries between third world laboratories/plant breeders and the leading biotechnology laboratories of the world. These leading laboratories can furnish products and services to

laboratories and plant breeders in third world countries that will be needed for successful plant breeding in the 21st century, but that neither the developing countries nor the IARCs can now afford to develop on their own. In other cases, the IARC biotechnology laboratories might be able to work in collaboration with third world plant breeders and laboratories to create products that the third world countries could not produce alone.

A further essential service of the IARCs could be as a reservoir of legal experience, ready to help third world countries in licensing and/or exchange activities involving intellectual property protection. Training courses for those interested in licensing genes might become as common as present training courses for those interested in conducting on-farm yield trials. In this area perhaps the Consultative Group on International Agricultural Research (CGIAR) could provide a basis of expertise for the IARCs.

As with all their activities, the IARCs should strive to help the developing countries to build up their own expertise in these matters, within limits of each country's capabilities and needs. The goal for developing countries, in turn, should be to participate actively and equally among nations in the biotechnological aspects of plant breeding while protecting and enhancing their own (broadly defined) national interests.

Equality of Opportunity and Responsibility

As they develop and use their biotechnology capabilities, individual developing countries and their institutions--both public and private--should define and act on the unique comparative advantage they may have in such things as genetic resources, abundant labor, resourceful small businesses, and equable climate. These advantages can be successfully deployed in accordance with the rules and customs of the industrial nations, although some additional conventions will need to be devised for the new factors arising from developing countries. For example, new international conventions must be devised to promote reliable conservation and efficient, but fair, exploitation of the abundant but rapidly disappearing genetic resources that still can be found in farmer varieties and natural ecosystems of developing countries.

An important consideration for developing countries will be to refrain from insistence on special concessions such as exemptions from existing international conventions on intellectual property protection. Such exemptions will hinder rather than help the developing countries in application of biotechnology to plant breeding. Allowances must be made for lack of infrastructure and/or information in individual developing countries, but if the goal is to promote the spirit of the conventions, satisfactory accommodations can be made.

Achievable Rates of Growth

In the end, the fundamental question is: Can rates of growth in food production for third world nations be brought in line with rates of growth in demand? Experience during the past 50 years in industrial nations indicates that a combination of advances in breeding and other technology was able to support production increases of from 1 to 3 percent/yr, depending on crop and region. These rates, highly dependent on increasing use of synthetic nitrogen fertilizer, are probably going to decline as fertilizer use levels out or is reduced in amount. About 50 percent of production gains in all major field crops in the United States have been the result of advances in breeding, but changes in breeding in large measure were made to allow crops to take advantage of added fertilizer and improved weed control measures.

The question today in the industrial countries is whether breeding can continue to improve yields without the opportunity to interact with new kinds and amounts of chemical inputs. The evidence is that breeding still has

great power to provide added protection from environmental and biological restraints to production and that, properly focused, breeding can by itself continue to provide productivity increases at rates of 1 to 2 percent/yr in the industrial countries.

For third world countries, it seems technically possible to provide, during the next 25 years, production increases per hectare of 3 percent or more. Breeding, agronomic practices, and limited amounts of chemical inputs all have much to add in many parts of the developing world. It will be important, however, to avoid the mistakes of the industrial countries, such as overuse of nitrogen fertilizers (either synthetic or natural) or contamination of groundwater supplies with pesticides. Intimate knowledge of crop biology and its interactions with local environmental and sociological conditions will be the cornerstone of production increases in the third world.

Two probable constraints to achievement of these rates of growth in the developing world are lack of infrastructure--and the political stability that allows it to develop--and lack of capital investment in agriculture, from either indigenous or foreign sources. Without at least these two foundations, achievement of high rates of growth in food production capacity in the tropics and subtropics seems unlikely.

Summary

Technologies in the 1990s will be extensions of technologies of the 1970s and 1980s, but they will need expansion, refining, and localization. New varieties should be able to withstand locale-specific environmental constraints and also give maximum yield in absence of constraints. A major requirement will be development of synergistic breeder-farmer relationships to force faster and surer development of productive and reliable new crop varieties adapted to continually more productive farm practices.

Investment in plant breeding must increase to keep rates of improvement from declining. Investment in biotechnology must be initiated and/or increased to provide a basis for advances in the 21st century. In addition, the IARCs must broaden their mission, becoming sources of biotechnology expertise and products and agents of biotechnology information and product transfer.

Developing countries will need to be active as equals among nations in utilization of licensing and other applications of intellectual property protection for products and processes of biotechnology.

There are no foreseeable limits to potential genetic improvements in productivity of the major field crops for the third world, for example, rice, wheat, and maize. But to maintain or increase improvement rates will require increased and consistent investment in broadly conceived plant breeding.

A new goal will be developed for crop research in the tropics and subtropics in the 1990s: to increase total profitability rather than to simply increase crop yields, and to do so in an ecologically and economically sustainable fashion. Its achievement will require holistic thinking and systems management procedures, and advancement toward the goal must be farmer-led.

Notes

1. Single-gene dominant types of resistance are more suited to breeding programs for industrial nations than to those of third world nations because of the constant replacement and close monitoring they require. (Even the rich countries should limit their dependence on this type of protection.) Nations with limited financial and technical resources will be better off if

they breed out of gene pools with multifactorial or other more durable types of resistance.

2. This was not the famous 1970 epidemic of southern leaf blight, race T. The 1970 epidemic was based on uniformity of a cytoplasmic gene. The problem in the 1940s was based on uniform susceptibility of nuclear genes.

3. "Leading," as used here, is not a synonym for "rich" or "powerful." It is applied to farmers well known in the neighborhood for good husbandry and common sense.

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DEVELOPMENTS IN ANIMAL TECHNOLOGY

Cees de Haan

Driven by a fast-expanding demand, the developing world has moved from a meat and milk surplus in the early 1960s to a net deficit of about 2.4 million tons of meat and 16 million tons of milk equivalent, at a total value of \$7 billion in 1987 (FAO 1988). With growing urbanization and rising incomes pressing demand further, it is estimated that this gap will widen dramatically over the next decade.¹ For reasons of food security, this increasing trade gap must be addressed.

Although past growth in meat and milk production in the developing world resulted mainly from an increase in animal numbers (table 1), now that natural feed resources in many parts of the world are reaching the limits of their carrying capacity, future growth will have to come from increased productivity per head. A greater use of improved technology will be the key factor to achieve this goal.

This paper will provide a broad overview of recent technological developments in the livestock sector, especially those that can be expected to have a practical impact on the Bank's project work in the 1990s. It focuses on new technologies in livestock feeding, referring only to animal health and breeding technologies as they affect feeds and feed supplies. Feed technology is the central theme of this presentation because of its overriding role in determining growth and sustainability of the sector and because of the many linkages between animal feeding and other agricultural issues, such as crop production and sustainable land use.

The paper is in four parts. First, developments in pasture improvement will be reviewed. Second, recent research findings in improving the use of fibrous crop residues will be described. These two parts will thus focus on ruminant (cattle, sheep, and goats) nutrition. Third, the trends and technologies causing the progressive shift toward more feed grain-intensive production--of special relevance to pigs and poultry production--will be analyzed. Finally, the implications of these technological developments for research and extension will be briefly discussed. Throughout the paper, the focus will be on conventional scientific and biotechnological developments, available technology, and technology gaps.

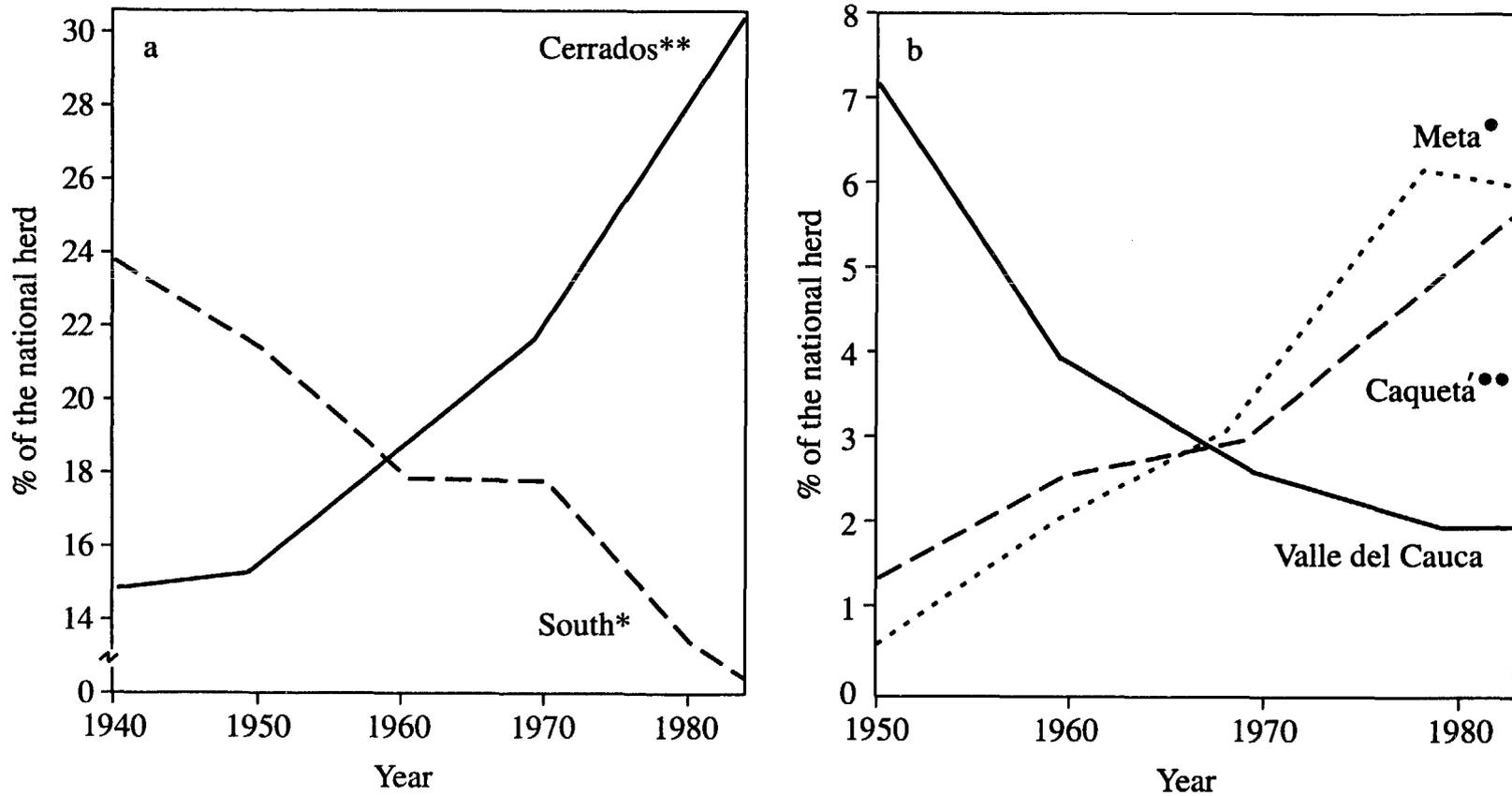
Pasture Improvement

High-Potential Areas

Scope and focus of improvements. The focus in tropical pasture improvement has been--and will continue to be in the next decade--the subhumid savannahs of Africa and South America. In Africa, this area constitutes the 4 million square km of subhumid savannahs, previously heavily disease-infested, notably with tsetse-transmitted trypanosomiasis ("sleeping sickness"), and therefore relatively empty. Four recent economic and technological developments, however, have caused dramatic changes in the nature of the tsetse problem. First, increased population and denser cropping and road networks are destroying the tsetse fly's habitat (Jordan 1986). Second, drugs and possibly acquired tolerance are enabling large numbers (20 to 30 million) of so-called trypano-sensitive Zebu cattle to move into tsetse-infested areas. There is increasing circumstantial evidence that continuously

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Figure 1. Regional Shift of Cattle Industry: (a) Brazil (*Rio Grande do Sul and Sta. Catarina; ** Goiás and Mato Grosso); (b) Colombia (•Savannahs; ••Rain Forest Areas)



Source: Toledo et al. 1990.

Table 1. Trends in Cattle and Pig Populations and Average Livestock Production Parameters in the United States and the Developing World, 1960-65, 1988

Item	United States		Developing world	
	1960-65	1988	1960-65	1988
Milk production (l/lactation)	3,060	6,306	575	766
L.W. per cattle (kg/year)	80	110	15	17
Cattle (millions)	103	99	564	858
Pork per pig (kg/year)	91	112	36	54
Pig (millions)	241	337	289	485

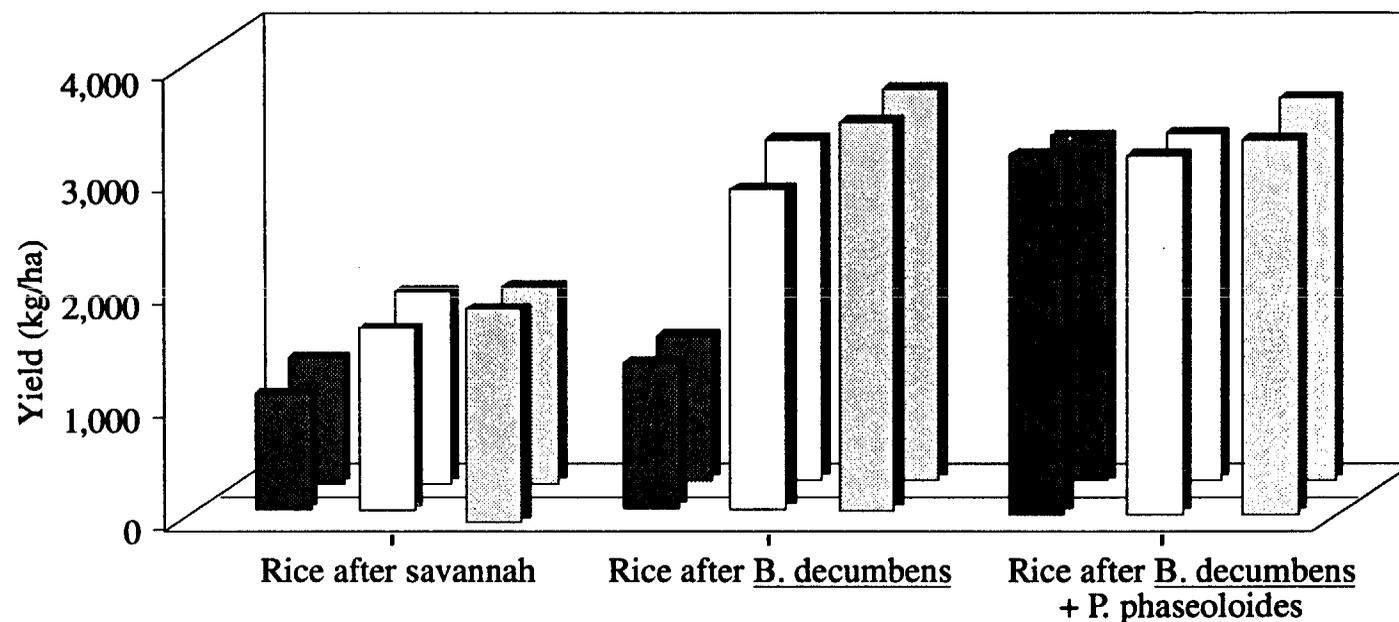
Source: FAO Production Yearbooks.

exposed Zebus, previously thought to be highly susceptible to trypanosomiasis and unable to survive in tsetse-infested environments, are acquiring some tolerance of the disease. Third, following ILCA's pioneering work showing the excellent productivity of trypano-tolerant breeds such as the N'dama, premium prices are being paid for these cattle, and the N'dama cattle population is expanding rapidly. Over the next decades, this expansion will be further accelerated by the use of embryo transfer and cloning techniques. Fourth, the use of fly-catching screens and traps in combination with artificial attractants has shown that it is possible to reduce the tsetse population to very low levels (5 to 10 percent of the original population [Cuissance 1989]). This environmentally safe technique is one of the major new developments in tsetse control and is being widely introduced in several countries. Over the next decade, the four developments together (increased population, acquired tolerance, multiplication of trypano-tolerant breeds, and nonpolluting fly control methods) will rapidly occur in this zone, seriously endangering its fragile resource base (Audru et al. 1988). In addition, the natural vegetation of the subhumid savannahs is severely protein-deficient in the dry season (Saleem 1985).

The subhumid savannahs of South America constitute 1 million square km and have poor acid soils. Recent livestock numbers have risen rapidly, as increasing land pressure on the better soils in Brazil and Colombia pushes livestock onto more marginal savannahs (Toledo et al. 1990) (figure 1). Although less fragile than the African savannahs, the chemically poor soils in this zone, with toxic aluminum levels and high biotic pressure, prevent continuous cropping. In both the African and South American subhumid savannahs, therefore, the focus is on developing agropastoral systems, rotating pasture and crops, and including legumes or legume/grass mixtures to maintain soil fertility and alleviate the dry season protein deficiency.

Past experience. Past forage--especially forage legume introductions--has not, however, been very successful. Henzell (1988) points to technology gaps as a contributing factor, especially in the complex management of forage legumes and grass/legume mixtures and in the inadequately developed legume seed production technology. These major factors explain the rather successful adoption in Latin America of sown grasses (40 million ha), compared with the poor adoption of the technically much more rewarding grass/legume technology (0.5 million ha). The seed and management technology gaps are also major reasons for the failure of (a) the phosphate/clover technology in Bank-financed beef ranching projects in South America (PCR Uruguay Agricultural Development Project), with much lower persistence than estimated at appraisal; (b) CIAT's earlier attempts to introduce grass/legume mixtures in the acid soils of the Colombian plains, which after 15 years of CIAT research and promotion resulted in only 3,000 ha of the mixture sown (CIAT 1990); and (c) the cereal/medic technology in North Africa and the Middle East, which, despite 30 years of experimentation, demonstration, and substantial resources from CIMMYT, FAO, and bilateral donors, has only had limited adoption (Oram 1989). Cocks (1986) mentions lack of adopted

Figure 2. Rice Yields after Native Savannah Grassland and Improved Pastures at 25 kg P/ha (Columns in Background), at 50 kg P/ha (Columns in Foreground), and at Three Levels of N ( = 80 kg N/ha,  = 40 kg N/ha,  = no N) (Taken from CIAT 1989)



Source: Toledo et al. 1990.

cultivars, lack of seed, and inadequate understanding of the nature of technology transfer as the main factors of the nonadoption of earlier cereal/medic technology. These factors are the focus of ICARDA's current research.

McIntire et al. (1990), in highlighting the economic factors, concludes that sown forages will only be adopted if and when (a) population density reaches levels so that access to open natural grassland becomes severely restricted, and (b) the forages compete with crops in returns per ha and man-day. Comparable returns normally occur only when forages are used to produce high-value outputs (milk, fattened animals) or have an additional benefit beyond their direct contribution to animal feeding. This explains the failed introduction of artificial pastures in West African beef ranches (Doppler 1980) and the relative success of the South American phosphate/clover technology with dairy producers. Social factors particularly related to land tenure and use of fallow land might impose further constraints, especially in the lower rainfall areas. Lack of clearly defined users' rights of the fallow land was one of the constraining factors in the adoption of the cereal/medic technology (Cocks 1986).

Current thrusts. Current efforts consider the earlier technology gaps and socioeconomic factors, focusing on low-input grass/legume mixtures as part of integrated crop/livestock production systems. Two of the more promising thrusts are:

1. ILCA's legume fodder banks, which are established under a low-input system (small quantities of phosphate and limited fencing) in the native savannah, or are undersown in cereal crops. Yields of cereals sown after the fodder bank are twice as large as those from crops sown in native savannah (ILCA 1988), and although the impact of the fodder banks on milk yield and fertility of traditional Fulani herds is difficult to assess, the technology is currently spreading readily (ILCA 1990);
2. CIAT's (1990) rice/pasture production systems, in which the rice foundation crop pays for the initial establishment of the improved pasture without affecting the forage yields. The legume/grass pasture doubles daily livestock gains, breaks crop pest cycles and weeds, and improves the soil structure and fertility, resulting in rice yields that are about 200 percent higher (3 tons per ha) than rice sown on native savannah (figure 2) (Toledo et al. 1990).

Another successful area of forage introduction is smallholder forage development for dairy production. The most significant success occurred in the Kenyan highlands, where as early as the late 1970s cut and carry systems with planted forages were practiced on 10 percent of the smallholdings (Stotz 1979). Since then, the level has increased to about 40 percent. Throughout this period, gross margins of artificial pastureland have been better than maize- and beans-cropped land and second only to tea and coffee (Stotz 1979 and Kenya Sector report 1990), which probably explains the high adoption rate. Currently in a number of Bank smallholder dairy projects (Ethiopia, Uganda, Madagascar, and India), farmers are given a "menu" of fodder production technologies, such as strip sowing, undersowing, and oversowing, and a wide choice of species. Seed production is organized through farmers' associations. Adoption of this package of technologies has been particularly promising with Ethiopian smallholders.

Low-Potential Areas

Scope for improvement. Spurred by the recent African droughts, a considerable amount of arid rangeland research has been carried out over the last decade. These studies did not yield, however, technologies that

Table 2. Production Parameters from Sahelian, Australian, and U.S. Dry Rangelands

Region	Protein production (kg/yr)		Fossil energy input (000 kcal)
	Per hectare	Per man-hour	Per man-hour
United States	0.3-0.5	0.9-1.4	25-35
Australia	0.4	1.9	150
Sahel			
Nomadism	0.4	0.01	0
Transhumance	0.6-3.2	0.01-0.07	0

Source: Breman and de Wit 1983.

increased rangeland production; they primarily concluded that present rangelands are used near capacity. Breman and de Wit (1983) demonstrated this in Mali, showing that the Sahelian rangelands were as productive as the Australian and U.S. rangelands under similar rainfall conditions (table 2). They concluded--as have many others--that the intensification of crop production in the adjacent higher rainfall areas and increased use of crop by-products would be the main candidates to augment the productivity of these pastoral systems.

Overgrazing and degradation. The assumption that heavy grazing is the prime cause of range degradation and that reducing the stocking rate leads to range improvement is increasingly being challenged, in particular for rangelands under erratic rainfall regimes, such as those in the Sahel and North Africa. First, Ellis and Swift (1988) argue that the great climatic variability overshadows the influence of livestock or wildlife on the range and that range productivity is more a function of climate than of stocking rate. Thus, the effect of livestock populations on the vegetation is sporadic rather than continuous, and drought rather than overgrazing depresses livestock populations. The regenerative capacity of the herd in good years is frequently too low to keep up with the recovery of forage production. Second, there is the increasingly important holistic resource management (HRM) movement in the United States (Savory 1988), which holds that range degradation is a result of set stocking with dispersed animals, causing continuous grazing and thus depletion of some plants (resting and thus rotting of others) and soil crust formation (with less germination of new seedlings). The application of HRM normally implies an increase in stocking rate, combined with a carefully monitored, short-duration, high-intensity rotational grazing. Although still heavily debated in the scientific community, HRM is gaining increasing acceptance in the U.S. ranching community and is being introduced in Africa in common land tenure situations.

Thus, with technological breakthroughs concerning increased biomass production in arid rangelands unlikely over the next decade, an incremental approach, emphasizing better management of available resources, concentrating on improvements in crop residue management, and making allowances for droughts, is required. Recent Bank range projects reflect this approach and emphasize the strengthening of pastoral institutions and their traditional grazing rights and the use of their traditional disciplines in implementing simple conservation and grazing management techniques.

Crop Residues

Scope for improvement. With 6 kg per tropical livestock unit (TLU)² per day available (more than half the required intake), crop residues are a key element in tropical ruminant nutrition. Their main drawback lies in their low feeding value because of their high fiber (lignocellulose) and low protein content. The focus in crop residue technology has therefore been on

quality improvement. The main methods used are chemical treatment, plant breeding, and rumen fauna manipulation.

Chemical treatment. Earlier treatment techniques to make lignocellulose in crop residues more digestible used sodium hydroxide or similar caustic materials. These approaches, however, proved inefficient in energy use and hazardous and unsuitable for small farm adoption. More recent technologies use ammonia and urea and are better adaptable to small farm conditions. Conclusive scientific evidence now exists to show that the digestibility and intake of straw improve by more than 20 percent when treated with urea or ammonia (impregnation during 2- to 6-week period) (table 3). Farmers' adoption has been limited, however, because of unfavorable economics and limited availability of urea in many developing countries. Direct feeding of urea, together with some minerals and an easily digestible carbohydrate such as molasses, improves digestibility and intake of straw by about the same amount as the impregnation treatments, but it is less costly. This molasses/urea block technology is now one of the inputs in Indian dairy development and is reportedly resulting in a cost reduction in milk production of about 20 to 25 percent (Leng and Preston 1988).

Table 3. Effect of Urea Treatment on Intake and Digestibility of Straw, and of Bypass Protein on Cattle Growth Rate (g/day)

	Straw	
	Untreated	Treated
Digestibility of dry matter (%)	39	47
Intake of straw (kg/d)	5.6	7.9
Cottonseed cake		
0	38	236
0.4 kg	365	497
0.8 kg	292	601

Source: Leng and Preston 1988.

Additional improvements. A potentially exciting new dimension of the ammonification and urea/molasses techniques could result from the work of Leng and Preston (1988). They show that supplementation of already treated straw with a source of protein meal, which is not degraded in the rumen (so-called bypass protein, i.e., cottonseed cake or fish meal) increases the intake and production response of treated straws and leads to production levels claimed to be similar to those obtained with grain-based diets. Leave protein of some fodder trees such as Leucaena and Gliricidia would have the same bypass effect. Further research is required, but the improved understanding of rumen protein metabolism that is emerging might have significant ramifications for the feeding technologies of the coming decades.

Plant breeding. Work to improve the feeding value of crop residues through plant breeding has until recently received little attention, and in fact the introduction of green revolution varieties generally reduced the feeding value of crop residues. For example, maize stover and barley stubble from traditional varieties in Mexico and Syria, respectively, sell four times more than improved varieties (McDowell 1988). Only recently have the international centers started to realize that the adoption of improved varieties by smallholders is hindered by this decrease in the feeding value of the residues, and some of the IARCs (notably ICARDA) have now begun to pay more attention to residues in their plant breeding work. There are tradeoffs to be made, however, as shown by Reed et al. (1986) in sorghum selection, in which the increase in "bird resistance" was directly proportional to the decrease in digestibility.

Rumen fauna manipulation. A newer approach to improving the feeding value involves genetic engineering of rumen bacteria to improve their efficiency in breaking down lignocellulose. Although this approach is potentially very attractive, it will still take considerable time before specific results can be expected, because of the many microbes involved (Quirke and Schmidt 1988). The prospects of developing strains that break down specific feed toxins might be better, as demonstrated by the identification of the microbe that degrades the toxin in Leucaena, recently discovered to naturally occur in the Hawaiian cattle population and successfully introduced in Australian herds.

Cereals and Cereal Substitutes

Background

Scope. Although some of the forage production and crop by-products approaches for ruminants are promising, the quantum leap has to come from improvements in high-quality cereal/protein meals (concentrate feeds) fed to the most efficient converters of these feeds, poultry and pigs. Already over the last two decades meat consumption in the developing world has rapidly shifted from beef and mutton to poultry and pork (table 4), and this shift can be expected to accelerate as incomes and urbanization increase. The shift has benefited from the trend over the last decades of grain prices falling faster than livestock prices. As a result concentrate feed use has quickly grown (table 5). Between the late 1960s and the mid-1980s, concentrate feed use in the developing countries (excluding China) grew at an average rate of 4.8 percent per year, more than double the growth rate in the developed world (Sarma 1986). Already about 45 percent of world grain production is now used for animal feed, and although this represents only 22 percent of the grain produced in the developing world, the percentage can be expected to increase there as well. A greater use of cereals for feed will provide an additional outlet for cereals and thus result in better security for small farmers in the developing world. It also will pose an additional challenge, because by 1984 the developing countries had already imported more than 15 million tons of cereals. Essentially, increased use of cereal for feed will mean that the growth of the pig and poultry sector will be the key factor determining grain deficits in the developing world. Moreover, such deficits and imports can increase quickly, as in Nigeria, for example, when during the oil boom, production of white meat increased by 9 percent per year and feed grain imports rose 49 percent annually (Mellor 1988).

Table 4. Meat Production in the Developing World

	Meat production (M tons)		Annual growth (%)
	1961-65	1986	
Bovine	8.2	12.8	1.7
Sheep and goat	1.4	2.3	2.0
Pig	2.4	6.0	3.7
Poultry	1.4	8.7	7.6

Source: Sarma 1986 and FAO Production Yearbooks.

Imported feed versus imported meat. Importing feed grain is normally economically justified, because it is about 10 times more expensive to transport 1 kg of meat from the United States to the developing world than it is to transport 1 kg of grain (table 6). Thus, with an average requirement of 2.5 kg of feed to produce 1 kg of poultry meat and 4 kg of feed to produce 1 kg of pork, it is more attractive to import grain than to import meat.

Table 5. World Cereal Feed Use, 1970, 1980, and Projections to 2000 (millions of tons/year)

Region	1970	1980	2000	Per LU (1980) (kg/yr)
Sub-Saharan Africa	1	4	8	40
North Africa/ Middle East	9	21	56	310
Asia ^a	5	31	68	260
Latin America	19	41	112	310
Total	34	97	244	150
Developed World		507		1,170

a. Does not include China.

Source: Sarma 1986 and several FAO Yearbooks.

Table 6. Comparative Transport Cost for Meat and Grain (U.S. dollars/ton)

Item	U.S. gulf ports to:	
	Rotterdam	Middle East
Grain	10	33
Frozen meat in cartons	200	340

Source: Cunningham 1990.

Future Developments in Concentrate Feed Technology

Increased protein efficiency. The main focus in concentrate feed technology will need to be on improving protein feeding. National feed balances from, for example, China, all East Bloc countries, and Madagascar show significant protein deficiencies. This is the result of the attention paid to cereal rather than to protein meal technology and of the previously mentioned accelerated shift to pigs and poultry production, which requires a much higher quality and quantity of protein than ruminants. The quality and quantity of protein are important factors affecting the efficiency of cereal use, and a better protein provision directly saves cereal feed. Protein feed technology will therefore be the focus in the 1990s.

Some of the key developments include:

1. a better "targeting" of the feed digestion in the digestive tracts, through pelletization, coating, and enzymatic protection to bypass the rumen digestion in cattle, sheep, and goats and ensure that the protein is only digested where it can be immediately absorbed. This offers good opportunities to realize more returns on costly concentrate feeds (McDowell 1988);
2. improvement, through genetic engineering, of the efficiency of the bacterial strains used in the industrial production of the protein building blocks, the amino acids. The considerable progress made in the development of economical production processes for the three key essential amino acids (lysine, methionine, and tryptophan) will make it possible to formulate pig and poultry diets with less expensive protein meals than formerly thought possible;

3. enhancement of the amino acid composition of certain cereals (although not successful with classical plant breeding methods, for example, with corn at CIMMYT), which might have new opportunities through genetic engineering techniques (Quirke and Schmidt 1988);
4. use of less conventional cereals containing high levels of lysine, such as amaranth.

Cereal substitutes. A second area of feed technology development is the increased use of cereal substitutes such as cassava meal, sweet potato meal, and corn gluten feed. These substitutes have already become important components in the pig and poultry diets in the EEC over the last two decades. This was the result of significant improvements in feed formulation techniques and of internal EEC cereal pricing policies, which favored the imports of cassava meal from Thailand (7 million tons of cassava meal, or 15 percent of the EEC's total consumption of energy feeds). Future short-term expansion in the EEC is likely to be limited more by increasingly stronger protection movements of the EEC's own cereal production than by the true economic costs (cassava meal is already subject to "voluntary import restrictions" and was proposed by the EEC for increased levies under the "rebalancing" principle proposed for introduction under the GATT). However, at about half the price (f.o.b. Bangkok) and at 70 percent of the feeding value of coarse grains, cassava is also attractive for producing countries themselves and their neighbors. Research on alternative uses of cassava in animal feed is also receiving increasing attention, for example, in CIAT, and it seems likely that the role of dried cassava meal and other cereal substitutes in animal feeding in the developing world will increase.

Use of growth hormones. A third technological development in increasing feed efficiency concerns the use of growth hormones. There is a large body of scientific evidence that proves the increase in milk production and growth rate with the use of Bovine Somatotropin (BST) and the higher daily gain, better feed conversion, and better meat quality with the use of Porcine Somatotropin (PST) (table 7). These hormones, which naturally occur in the body, increase efficiency by allowing a larger share of the feed to be used for production purposes (Bauman 1989). The only technical questions probably not yet fully explored in BST (research on PST is less advanced) concern the effect of BST on the longevity of the animals, on the susceptibility of treated cows to udder infections, and on the injection-type delivery mechanism, which is inconvenient for widespread application, especially on smaller farms.

Table 7. Effect of Bovine and Porcine Growth Hormones on Key Production Parameters

	Percent increase
<u>Bovine growth hormone</u>	
Milk yield	10-30
Daily gain	5-13
Feed efficiency	6-20
<u>Porcine growth hormone</u>	
Daily gain	7-14
Feed efficiency	15-40
Backfat thickness	31-58

Note: Adapted from Quirke and Schmidt 1988.

The release of BST has been delayed by political pressure from both producers' and consumers' groups. Producers' groups fear the consequences of substantial increases in production leading to surpluses and therefore lower prices. The use of BST would also affect cereal production; for example, Bauman (1989) estimated that to produce the same amount of milk in the United States, BST would cause a drop in the demand of about 40 million tons of corn, equal to the production of 10 million acres. Consumers' groups oppose the release because of the association of the substance with other hormones such as the anabolic steroids used in cattle fattening (and by some athletes). Although the decisionmaking surrounding the release of BST is now highly politicized, BST is likely to be released in the United States in the near future, whereas the release in Europe and Australia is less certain. A general release would probably have a significant effect on the structure of dairy production. BST would favor the larger over the smaller producer and above all would favor dairy production in the temperate zones over the tropical areas, although little research has been done yet in the tropics on the effect of BST. With pig and poultry technology easier to transfer to the tropics than cattle technology, the effect of PST--when confirmed and released--could be more beneficial in the developing world.

Other technologies in feed-intensive systems. Large-scale intensive pig and poultry production has always benefited from Western technologies in housing, veterinary care, and breeding. More intensive smallholder pig and poultry production has been risky in the past, especially because of disease hazards. New developments in the veterinary field, such as thermostable vaccines and diagnostic kits, progressively reduce this risk. Diagnostic kits will greatly decentralize diagnostic services and are one of the most significant applications of biotechnology in the tropics.

Conclusion

The Need for Crop/Livestock Integration

The thrust that emerges from these new technologies clearly indicates strong linkages between crops and livestock. This is evident at the production unit level by the mutually beneficial relationship between grass/legume mixtures and crops in subhumid savannahs and smallholder crop/dairy farming in the African highlands and by the supplementary role of crops in the management of arid lands. The potential of new insights regarding the use of crop residue treatments and bypass protein in improving the use of fibrous straws also illustrates this thrust, as does the determining role feed grain plays in the total food security of the developing world. Outside the scope of this paper, it is of course also convincingly demonstrated by the animal traction and organic fertilizer linkages as well as by the role of livestock as insurance against risk and as a generator of cash to buy inputs for crop production.

The Weak Institutional Linkages

Despite these strong technical and economic linkages, the institutional linkages are frequently weak. Livestock research in most of the developing world is carried out separately from crop research. Pasture research is primarily conducted without regard for the specific requirements that crops and crop rotation would demand from the grass. Similarly, crop research has traditionally only focused on the improvement of the grain yields, despite the high value that smallholders place on crop residues. Seed production research and development is heavily oriented toward food crops and pays little attention to forage seeds. For example, none of the current 14 free-standing Bank-funded seed projects included forage seed production. It is still one of the key constraints, especially concerning forage legume introduction. Livestock extension is frequently carried out by a service separate from crop extension. When attempts have been made to integrate the two services into a unified extension service, this integration has been weak, and livestock extension has been treated like a "second class citizen." There

are few examples of well-integrated crop/livestock services. Within the livestock services, research and extension is mainly oriented toward animal health improvements, as illustrated by the estimated 80 percent of the budget of African livestock services designated for animal health tasks. Animal health tasks can, however, be better handled by the private sector. Livestock, aided by modern technology, can play an important role in developing sustainable agricultural systems, but better integration of livestock in the agricultural institutions will be a key requirement.

Notes

1. IFPRI (Sarma and Yeung 1985) projected for the year 2000--assuming the same growth as during the 1966-77 period--a deficit of 21 million ton of meat and 64 million ton of milk, valued at current prices at about US\$60 billion. With the developing world's considerably lower growth over the 1980s, the actual gap will probably be lower, although still substantial.

2. Tropical livestock unit (TLU) is used to aggregate different livestock classes and species. One TLU equals an animal of 250 kg.

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CROP TECHNOLOGIES FOR THE 1990S

Jitendra P. Srivastava

Introduction

In the closing years of the 20th century, we can look back with legitimate pride and satisfaction on the accomplishments of crop improvements and food production. The rediscovery of Gregor Mendel's laws of genetics in 1902 established the scientific basis for plant breeding. The new seeds and the use of chemical fertilizers could be considered harbingers of modern agriculture. In the first 50 years of the century, the progress made in improving the yield potential of crops, as well as their security from diseases and pests, was modest (figures 1 and 2). However, the progress made in meeting global food needs has been outstanding during the second half of this century (table 1). From 1950 to 1990, global grain production increased from 631 million tons to 1,730 million tons. Maximum increase has come from cereals, particularly wheat, and rice. This progress has occurred as a result of large-scale adoption of green revolution technology coupled with necessary infrastructural support, pragmatic policies, and political will.

Today, however, many are questioning our ability to sustain such rates of increase in food production--or even to maintain current levels. Higher population growth rates; soaring use of grains for meat, dairy products, and industrial purposes; and relatively high elasticities of expenditure for food in the developing countries--all are expected to outpace the current rate of growth in food production. Since 1984, for example, per capita production of cereals worldwide has declined from 344 kg in 1984 to 325 kg in 1990, and the growth in production is unequally distributed in different regions (figure 3). In the food-exporting developed countries, supply has grown far more rapidly than demand, but in many developing countries the situation has reversed, and these countries are unable to purchase sufficient quantities of food to meet their growing demand. Despite the progress in food production in recent decades, significantly more food and feed must be made available to meet the increasing needs. Moreover, declining natural resources available for agricultural production and threats to the environment continue to pose challenges of varying proportions.

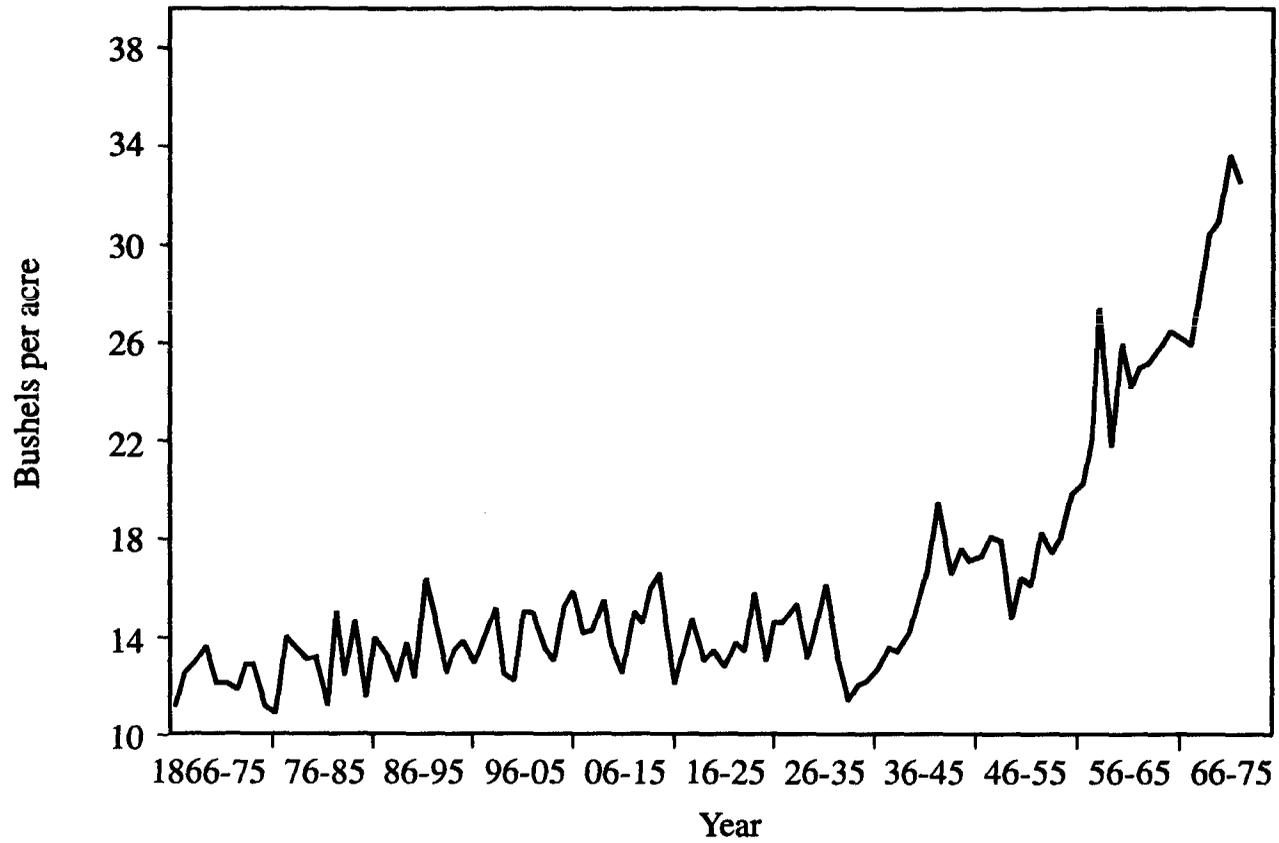
During the 1990s and beyond there will be a greater challenge than in the past to meet the food, fiber, and fuel needs of the growing population (figure 4). Technology requirements rise as population intensity increases and becomes more complex as the goals of productivity and sustainability are combined.

Crop productivity is a function not only of the genetic potential of the crop but also of the overall environment in which it is grown. Factors such as climate, topography, soil, water, nutrients, market demand, and farmer incentives determine the ultimate crop yield. People can modify both the crop genotypic potential and other factors to increase production.

Role of Improved Seeds

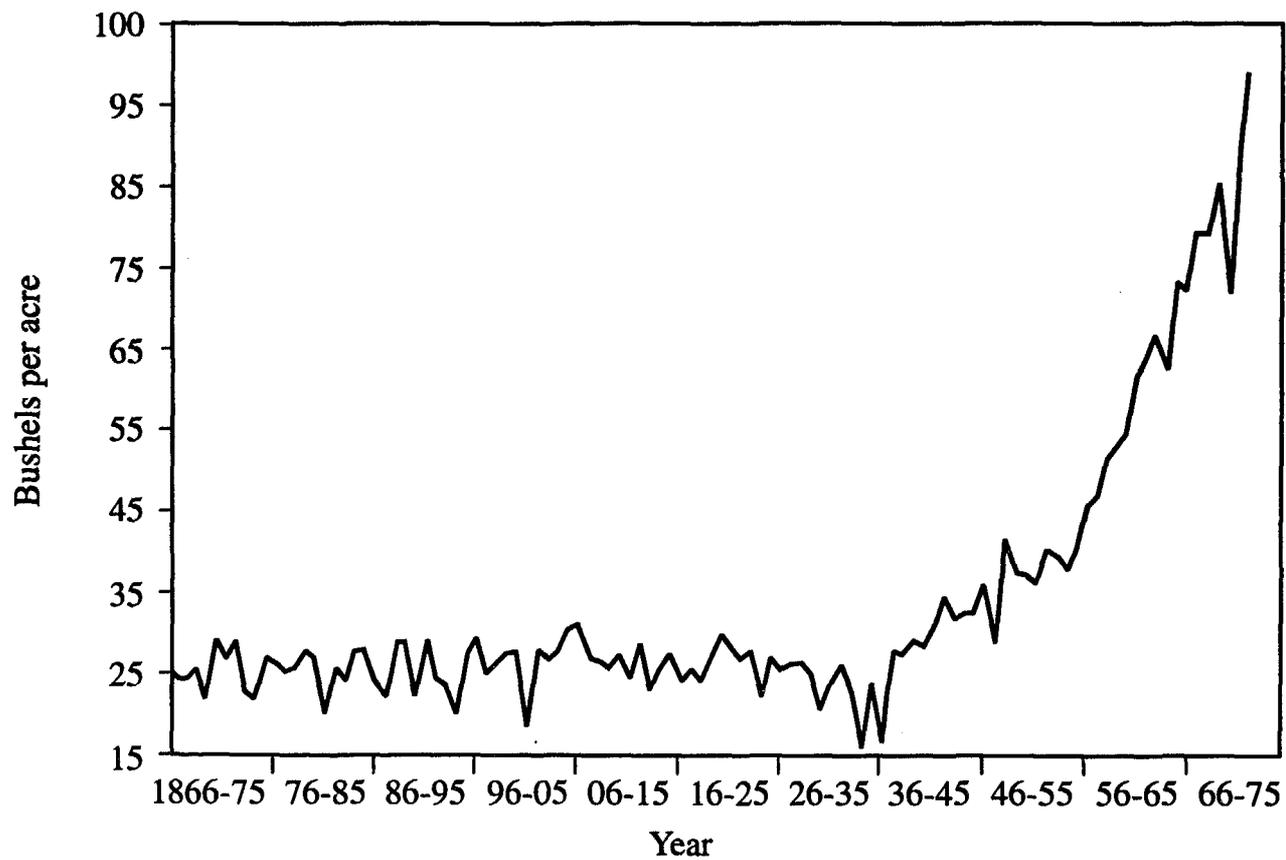
The genetic potential of seed is one of the key determinants of agricultural production. Seed is the input through which green revolution technology was transferred to farmers. In the future, seed will continue to

Figure 1. Wheat Yields per Acre Harvested in the United States, 1866-1972



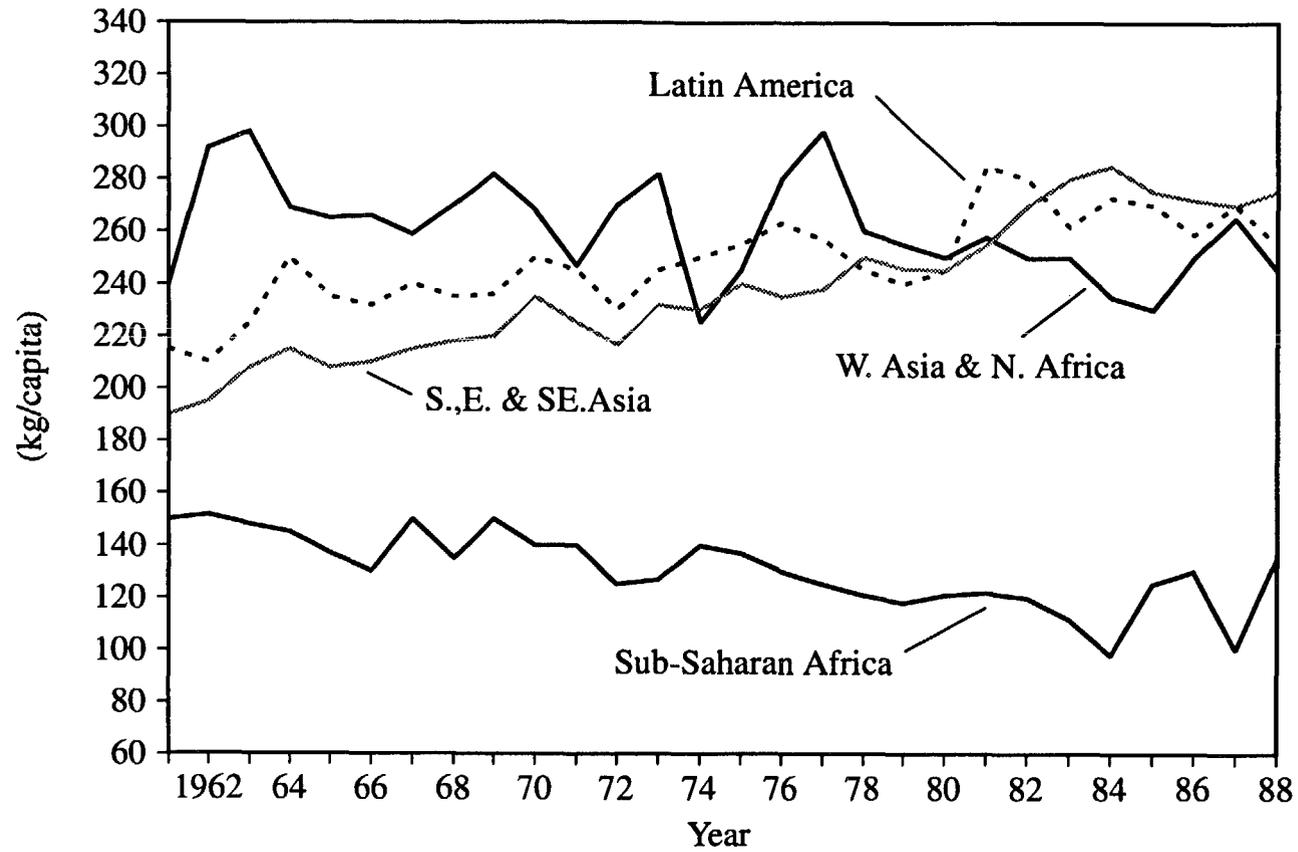
Source: Luttrell and Gilbert 1976.

Figure 2. Corn Yields per Acre Harvested in the United States, 1866-1972



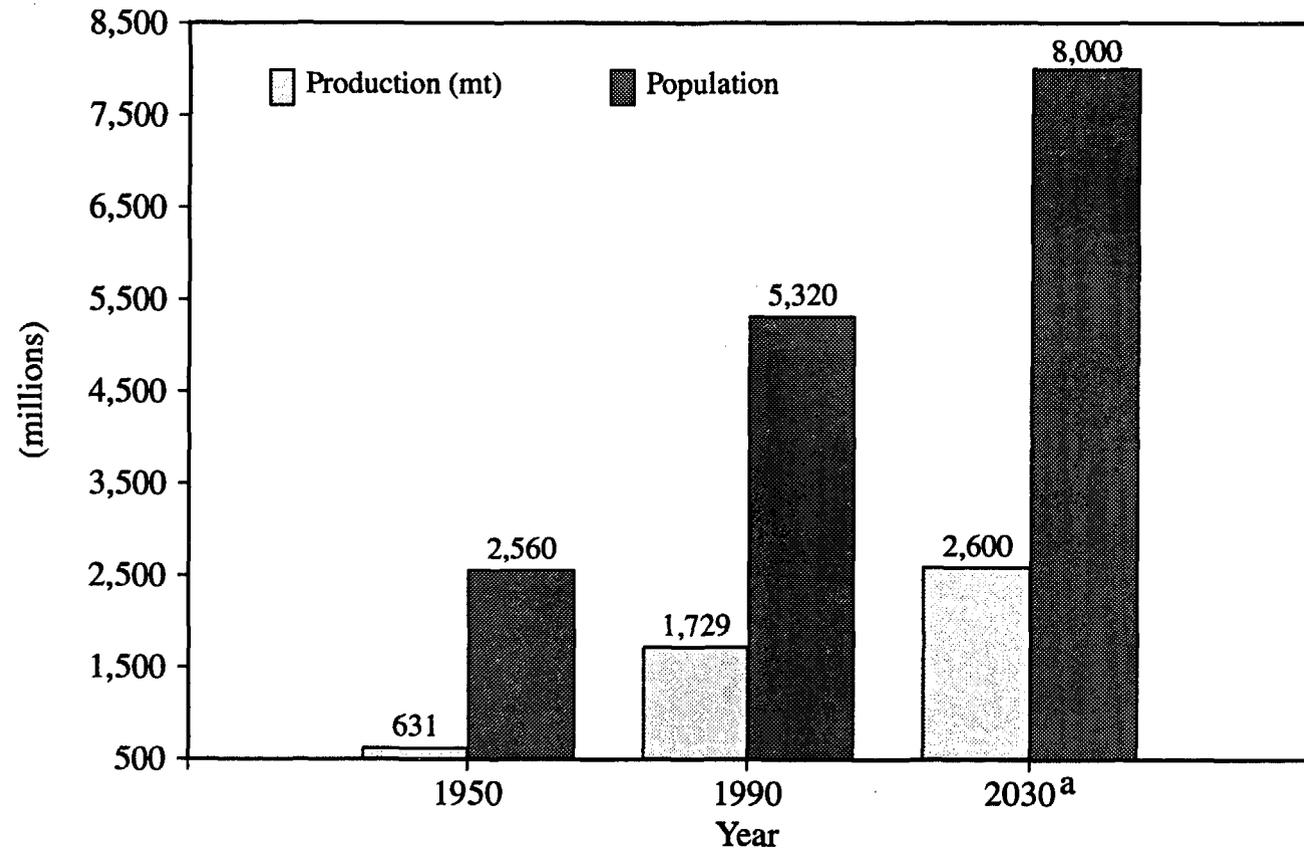
Source: Luttrell and Gilbert 1976.

Figure 3. Cereal Production per Capita by Developing Country Region



Source: CIMMYT 1989b.

Figure 4. World Population and Grain Production



a. Projected figures; production requirement based on 325 kg per capita production in 1990.

**Table 1. World Crop Production
(millions of metric tons)**

Crop	1950	1960	1970	1980	1989
Wheat	172	222	288	420	538
Rice (paddy)	153	151	293	375	506
Corn	139	224	260	394	470
Other grains ^a	21	42	64	84	89
Sugar	39	62	72	90	106
Soybeans	18	26	41	98	107
Potatoes	168	285	311	230	277

a. Other grains are sorghum and millet.

Source: Based on McMullen 1987.

be the input through which much of the new conventional, hybrid, and biotechnologies will be utilized by farmers to meet growing production and conservation demands.

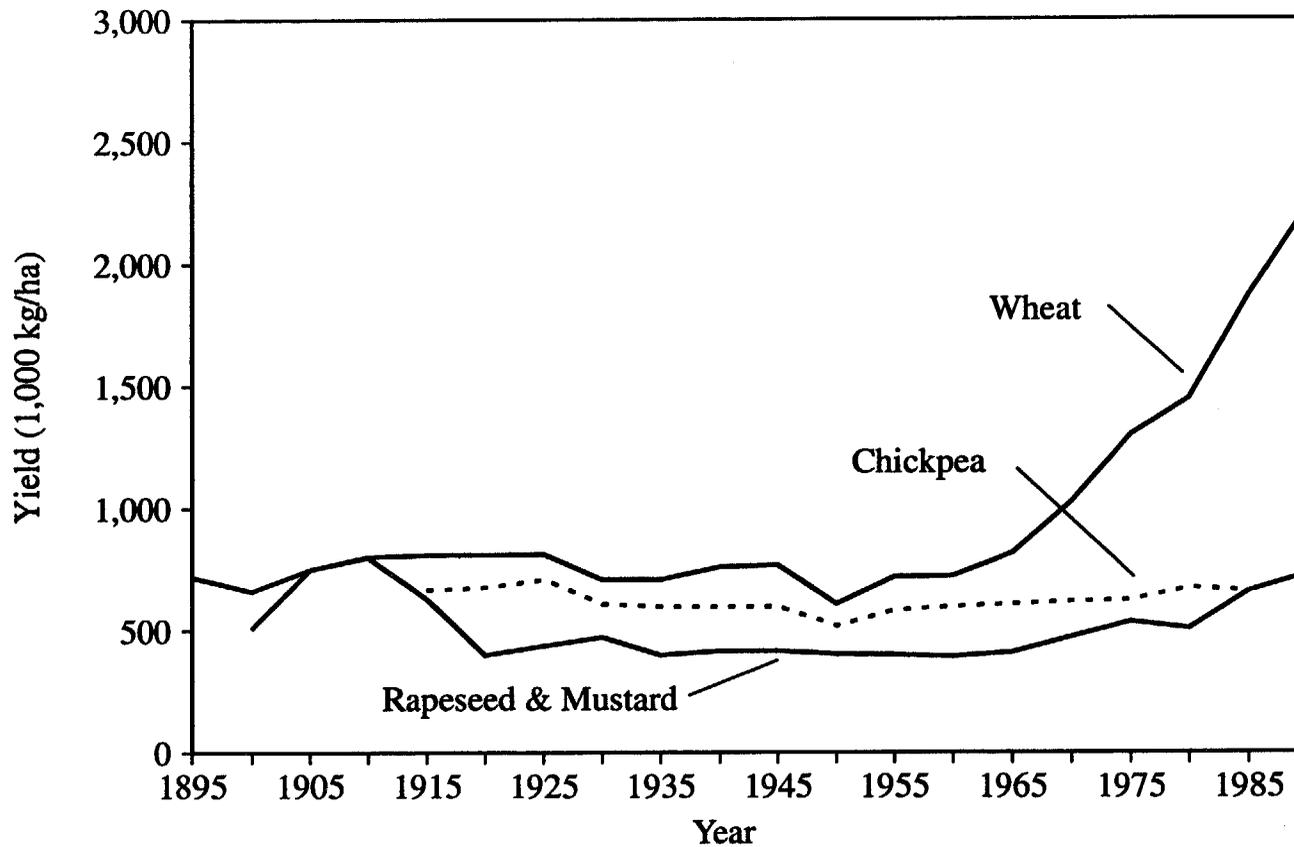
The yield potential of cultivars of some of the major crops has increased significantly over time (table 2). Introduction of new crops and varieties, development of cultivars tolerant of diseases, and insects and phenology matched with agroclimatic conditions contributed to yield enhancement and minimized various hazards. Since 1928 in the United States, yields of corn have been improved by a factor of about 5 (figure 2). Part of the increase has been the result of the use of fertilizers. At least half has come from the use of hybrid seeds (Abelson 1990). Wheat yields in the United States increased from a three-year average for 1958-60 of 1,700 kg/ha to an average of 2,200 kg/ha for 1978-80 (32 percent increase), and half of this yield gain is the result of crop improvement (Schmidt 1984). From 1950 to 1980, the sorghum grain yield in the United States increased at an annual rate of 7 percent (Miller and Kebede 1984). Hybrid seeds, better disease and insect resistance, improved agronomic practices, and irrigation contributed to this gain. Globally there have been yield increases for many crops, particularly wheat and rice.

Higher-yielding varieties of wheat and rice were the key factors of the green revolution technology that produced dramatic yield increases in large parts of Asia, Latin America, and Africa. The term green revolution is applied to the use and spread of dwarf, fertilizer-responsive, and early maturing wheat and rice varieties. Although several factors interact in determining the final yield, figure 5 demonstrates the importance of high-yielding crop technology. The figure indicates that in the absence of any major technological breakthrough in genetic potential, yield levels of wheat, chickpea, rapeseed, and mustard remained stagnant between 1895 and 1965 in India. The yield levels of chickpea, rapeseed, and mustard have not changed much between 1965 and 1990, whereas in the case of wheat, the advent of dwarf, input-responsive, and early maturing varieties pushed average yields of wheat in India from less than 1 ton/ha to over 2.2 ton/ha during the same period.

Limitations of the Green Revolution Technology

There have been many benefits from the green revolution in rice and wheat, and a major benefit has been increased food production and yield stability of crops (Plucknett 1990b). It is important, however, to keep in mind that the green revolution occurred largely in irrigated regions or in

Figure 5. Change in Crop Productivity of Wheat, Rapeseed & Mustard, and Chickpea in India since 1895



Source: Based on Sinha 1990.

Table 2. Rates of Gain in Wheat Yields from Wheat Breeding

	Period	Yield gain due to breeding (% per year)
Irrigated/well watered		
U.K.	1908-78	0.5
U.K.	1953-78	0.9
U.K.	1962-82	0.9
Mexico	1950-70	2.0
Mexico	1968-82	1.0
Pakistan	1957-82	2.0
Pakistan	1965-82	0.8-1.0
Dryland		
NSW, Australia	1947-80	0.6
Western Australia		
<325 mm rainfall	1960-86	0.3
325-450 mm rainfall	1960-86	0.5
Great Plains, U.S.	1943-77	0.6

Source: Based on CIMMYT 1989a.

areas of generally adequate rainfall. The ensured soil moisture reduced risk levels sufficiently to make investments in fertilizers, herbicides, pesticides, and improved agronomic practices feasible. Thus, the interaction between the high-yielding potential of the cultivars and improved agronomic practices was realized, leading to substantial net returns (Whitman and Meyer 1990).

In the past, increases in crop production have come about from expansion of land under cultivation, crop intensification, and yield improvements. During the 1990s, many parts of the developing world will approach limits to area expansion, and irrigated area under crops may decline. Water too is becoming a scarce resource. The quantity of water required for maximizing crop production is declining, and competing claims for other uses will significantly limit further spread of high-input technology.

Tomorrow's Crop-Growing Environment

During the past few years, there has been considerable concern about the social and economic aspects of environmental degradation resulting from overuse and misuse of high-input technologies. Global warming is likely to accelerate over the next three decades with associated changes in rainfall distribution. During the last two decades, several dramatic climatic fluctuations have occurred, causing poor crop production in several regions. Indications are that climatic fluctuations will become more pronounced over the next few decades.

During 1990 several World Bank studies and publications highlighted the increasing gap between food grain production and consumption; increased use of cereals for feed and industrial uses; declining areas in cereal crops; the slowdown or decline in irrigated land available for food crops production; maturing of the green revolution; growing restrictions on the use of chemical fertilizers, pesticides, herbicides, and plant hormones; declining trends in grain yields and production; slight impact of green revolution technologies in dry areas; and the likely impact of long-term climatic changes on food production and interannual coefficient of variability.

Crop Technologies for the 1990s

Perceptions of agricultural development needs have changed in the last few years. The green revolution technology, viewed earlier as the major answer to most of people's food and other agricultural needs, is no longer considered adequate and has never been intended for resource-limited agriculture. Pertinent questions include whether the presently available technologies would meet the needs of the 1990s for productivity and sustainability and whether we have the technologies to increase and maintain productivity of resource-limited areas.

Plucknett (1990a) states: "Because of the shrinking availability of cultivated land, gains in production will be from intensification rather than expansion schemes. Intensification will occur on both favorable and less endowed lands. On favorable land, with high input systems, better management will be especially crucial to achieving higher yields. For less endowed and marginal land, pressed upon by population, a combination of new cultivars and management practices will be required to achieve both greater productivity and yields." Therefore, crop technologies for the 1990s and the 21st century should:

- maintain and increase yields in high-resource base areas;
- optimize available resources for increased and sustainable yields in resource-limited base areas;
- conserve or enhance natural resources.

Potential of Available and Possible Yield-Enhancing Crop Technologies

To meet the needs of the 1990s and beyond, we may need further rapid technological inputs to spur comparatively dramatically higher, if not revolutionary, production. Technologies required to meet additional production goals could be divided into three groups, those that:

- increase yields through better management, including better services to the farmer, more efficient use of inputs and natural resources, and reduced production costs;
- reduce losses from diseases, insects, weeds, rodents, and birds through integrated pest management and improved postharvest technologies, including processing and marketing;
- seek genetic improvement through all methods available (including conventional breeding, hybrid technology, and biotechnology).

The remainder of this section will concentrate on yield-enhancing technologies using some crop examples.

Rice

Half of the world's 144 million hectares of rice are irrigated and produce nearly 75 percent of the world's harvest. In this ecosystem, the yield gap is closing: farm yields have increased steadily, but yield potential on research plots has not. Maximum yield potential of new rice varieties has hardly increased since the 1965 release of IR-8. Increases in productivity have been through the incorporation of disease and insect resistance, shortened growth duration, and improved agronomic practices.

International Rice Research Institute (IRRI 1989) strategies to raise the yield plateau of irrigated rice are to modify, once again, the rice plant type and to develop hybrid rices for the tropics. The first strategy uses a lesson from maize and sorghum. Primitive types used to produce many tillers but only a few small cobs and grain heads. Their plant architecture

has been altered so that now they produce only one shoot that bears large ears. That change raised their yield potential significantly. Modern rice varieties tiller profusely, but many do not produce panicles. The hypothesis is that the elimination of nonproductive tillers could direct more nutrients to grain production. IRRI has started making necessary crosses to pursue this line of research.

The first rice hybrid was released in China in 1975. Since then, the area under hybrid rice has increased consistently. Currently, F-1 hybrids are cultivated on about 13 million hectares. The yield advantage of hybrids over the best available conventional varieties in China averages about 20 percent. In 1986, the average yield of hybrid rice was 6,474 kgs per hectare. Hybrid rices have also been released for commercial cultivation in the Democratic People's Republic of Korea. However, development of hybrid rice for the Asian tropics is taking longer than in the temperate zones. Recently, IRRI has identified several hybrid combinations that yield up to 30 percent more than the best conventional varieties. It has intensified collaborative research on hybrid rice with India, and there is a good possibility that India will move into hybrid rice production. Hybrid rice technology appears promising to further enhance rice yields from high-resource regions. Development of suitable hybrid combinations for different ecologies, and improvements in seed production technology, has the potential to further increase yield levels in this decade and well into the next century.

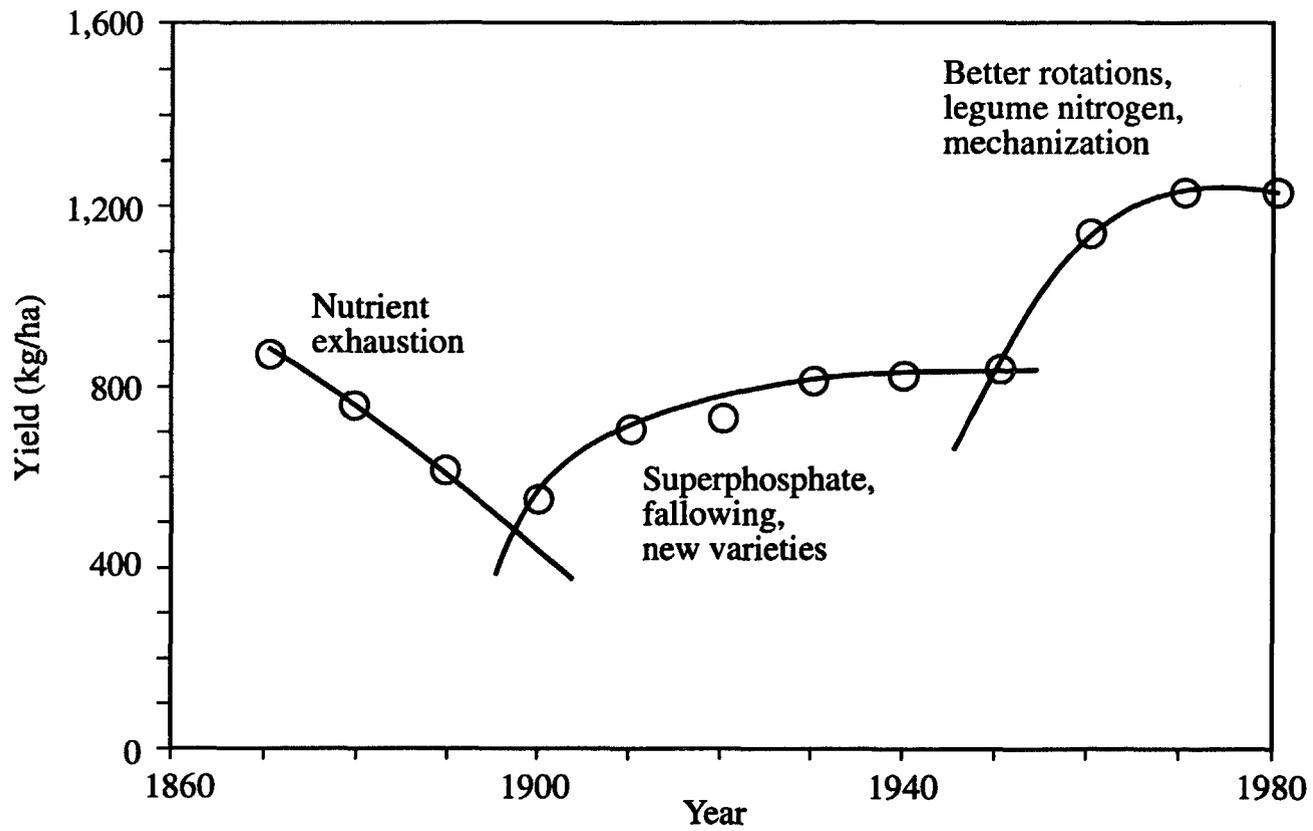
No varietal breakthrough is in sight for rainfed lowland, upland, and deep water rices. Here, improved crop protection and management will provide incremental productivity during the 1990s.

Wheat

Because of wheat's global importance, considerable research and development resources have been devoted to it, and steady progress has been made since the beginning of this century (figure 1). Rates of gains in wheat yields from genetic improvement for some countries are presented in table 2. However, use of Norin dwarfing genes, fertilizer, and irrigation dramatically increased wheat yields from the mid-1960s to the mid-1980s in many countries throughout the world and particularly in the Indian subcontinent and China. There is considerable literature on the impact of the green revolution on wheat production. Several World Bank reports (1990), however, indicate that in China, Bangladesh, India, Mexico, and Pakistan--the major beneficiaries of the green revolution technology--the rate at which wheat yields have been increasing slowed significantly during the past decade (table 3). One of the reasons for the declining growth trend is that farmers in the high-resource, major wheat-producing areas have already adopted most of the new technologies, and their management skills are such that they have already utilized much of the yield potential that the green revolution technology has to offer (Ruttan 1989). In addition, the mismanagement of soil, water, fertilizer, herbicides, and pesticides in intensive agriculture has started to cause soil, weed, disease, and insect problems. During the 1990s, small incremental increases will continue but no major yield-enhancing technology is on the horizon.

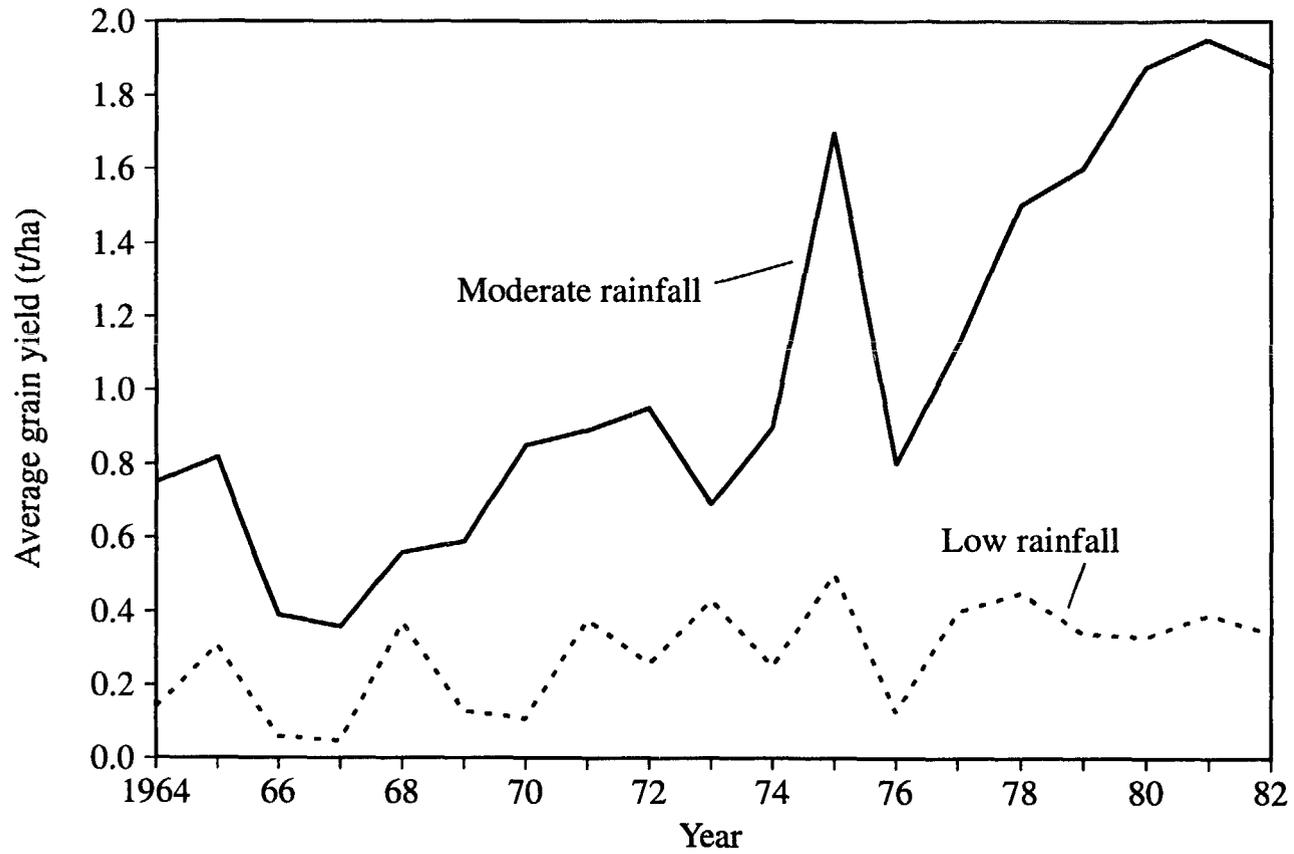
However, there is scope to increase yields further in moderate rainfall areas through the use of more drought-tolerant and pest-resistant varieties adapted to specific agroclimatic conditions and more efficient soil, water, nutrient, and crop management. The progress made in wheat yields under rainfed conditions in Australia provides an excellent example (figure 6). Compared with breadwheat, there is greater potential for yield enhancement in durum wheats and, in very dry areas, alternate crops should be grown in place of wheat (figure 7).

Figure 6. Australian Wheat Yields, 1860-1980



Source: Whitman and Meyer 1990.

Figure 7. Trend of Average Grain Yield (t/ha) for Bread Wheat in Two Rainfall Zones of Tunisia



Source: Srivastava et al. 1987.

Table 3. Changes in Growth Rates of Yields in the Major Wheat Countries of Asia (percent)

Country	Annual growth rate in wheat yields		
	1951-66	1967-77	1978-88
India	2.09	4.42	2.84
Pakistan	0.85	4.95	1.39
China	1.37	5.94	5.87

Source: CIMMYT 1990.

Maize

The early improvement in maize occurred through farmer selection, whereas further improvement at the beginning of this century came through use of the ear-to-row selection technique. Though the value of heterosis in maize was recognized in 1908, cultivation of hybrid maize on a commercial scale started in the 1930s after East (1928) devised a technique that made hybrid maize production practicable (figure 2). With this advance, hybrid maize by 1938 was being planted on about 55 percent of the maize acreage in the United States, and by 1945 practically the entire U.S. maize crop was devoted to hybrid maize. After World War II, hybrid maize spread to Europe and a few countries in Africa and Latin America. Because of location-specific adaptations, pest and pathogen resistance, and better vigor, single hybrids have been replacing the double-cross hybrids. By 1977, 80 to 90 percent of hybrid maize area in the United States was under single-cross hybrids. Use of hybrid maize is spreading in developing countries (figure 8).

In the high-input areas of the developed countries, the yields of single and double hybrids appear to have plateaued, and no new breakthrough is in sight. However, the potential of available technology for maize in the developing countries is vastly underutilized. One of the major contributing factors has been the inability of most of the developing countries to develop and produce hybrid maize seeds. Because of lack of seed production and distribution infrastructure, CIMMYT and most of the developed countries worked on development of open-pollinated composite or synthetic varieties with mixed results. Rapid growth of private seed companies in the last few years, increased research and development efforts, and remunerative prices have the potential to further increase maize yields in the developing countries.

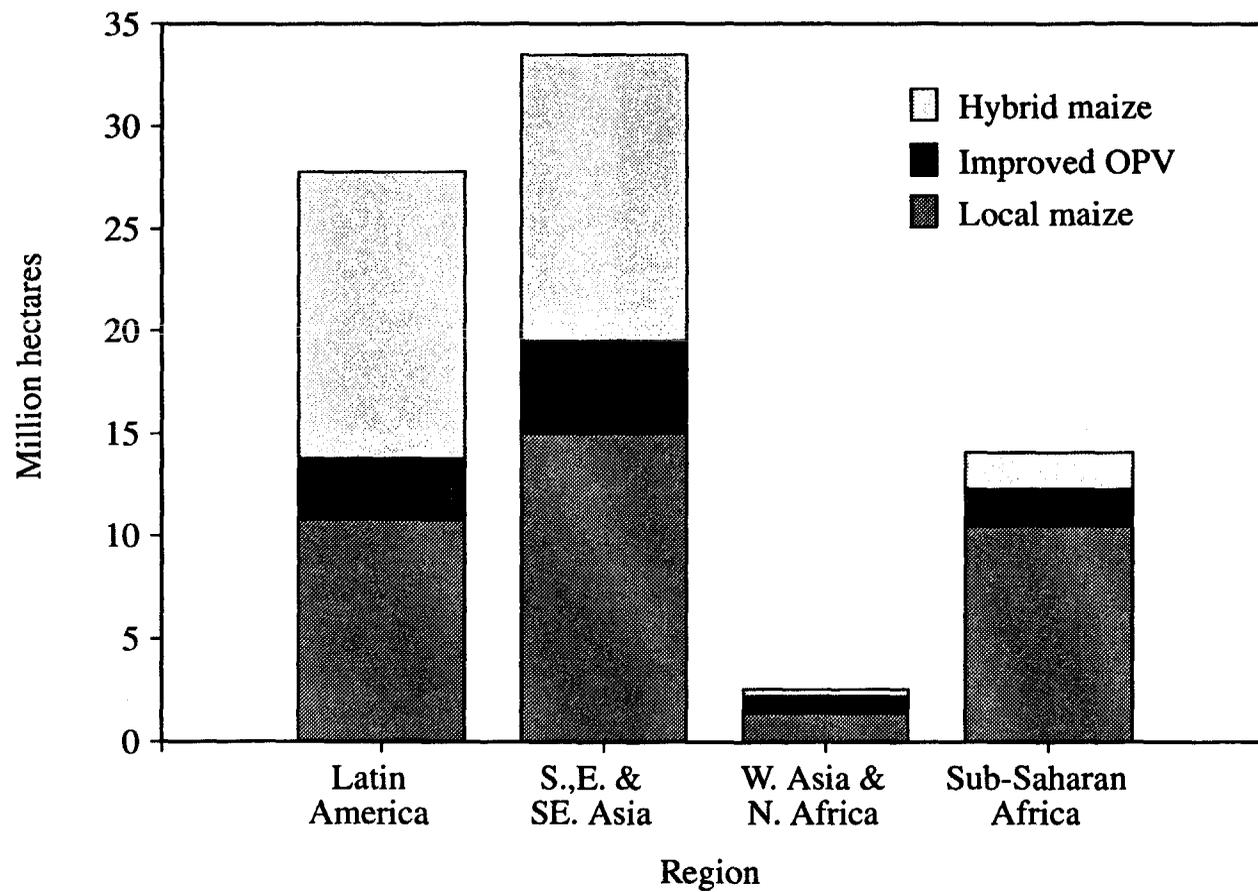
Barley

Barley is primarily grown in temperate climates and is considered a "poor man's crop" in the developing countries. In the dry areas, it is grown when no other crop is suitable and performs better than wheat in low precipitation areas (table 4). Relatively fewer resources have been devoted to this crop in the past, particularly for improving its productivity for low-input, marginal areas. A few varieties developed by ICARDA perform better in such areas (table 5). Systematic selections from existing barley landraces in Ethiopia and Syria are examples of developing low-input technologies with increased productivity for specific areas. Similarly, yellow rust-resistant barley varieties released in the Andean region have a much higher yield potential.

Pearl Millet and Sorghum

The importance of pearl millet to the resource-poor farmer in the hostile semiarid tropics of India and the Sahel cannot be overestimated. Pearl millet, unlike other major cereals, can be grown in areas with limited rainfall using little fertilizer and virtually no other input. Global millet production is about 35 million metric tons grown on about 45 million hectares. It is the principal cereal in the Sahel and in the arid states of Rajasthan

Figure 8. Use of Maize Germplasm by Developing Country Region, 1985-87



Source: CIMMYT 1989b.

Table 4. Grain Produced by Barley and Wheat (kg/mm moisture)

<u>Moisture (mm)</u> <u>(rainfall or irrigation)</u>	<u>Barley</u>	<u>Wheat</u>
200	7.5	1.1
300	8.0	6.1
400	8.7	5.6
500	3.4	8.7
600	5.6	7.8
700	4.7	11.6

Source: Srivastava et al. 1987.

Table 5. Performance of New Barley Cultivars in Rainfed Areas of Tunisia (220-440 mm), 1980-87

<u>New cultivar</u>	<u>Mean yield (t/ha)</u>	<u>Check cultivar</u>	<u>Mean yield (t/ha)</u>	<u>Percent increase</u>
Faiz	3.81	Ceres	2.79	36
Roho	3.43	Martin	2.64	30
Taj	2.66	Martin	2.17	22
Rihan	3.92	Martin	2.64	33

Source: Meeting the Challenge: Cereal Improvement in Tunisia 1988.

and Gujarat in India. It also forms an essential component of cereal production in central and southern India, southern Angola, northern Namibia, Botswana, and Sudan.

Yields in farmers' fields commonly range from about 100 kg/ha to over 2,000 kg/ha. Potential yield of new cultivars bred by ICRISAT and NARS is about 4,000 kg/ha. New cultivars provide acceptable yields in years of poor rainfall and excellent yields in years with good rainfall. The new cultivars are resistant to the most devastating disease, downy mildew, and respond well to moderate input technology while outproducing local landraces under traditionally low-input farming. The availability of short duration, downy mildew-resistant pearl millet cultivars such as WC-C75, ICTP 8203, and ITMV 8001 is spreading rapidly in several countries in Africa and in India (ICRISAT 1990).

The introduction of top-cross hybrids combine broadly based resistance to downy mildew and adaptation to heat and drought stress with the inherent vigor of hybrids. Seeds of these hybrids are being widely marketed in India and in some African countries. These developments in pearl millet open new opportunities for yield increase and cultivation of pearl millet in limited-resource areas.

Similarly, there has been success with constantly developing sorghum varieties and hybrids that are better adapted to prevailing agroclimatic conditions, are short duration, and have better disease resistance. They are being grown in Africa, Asia, and Latin America. There has been considerable progress in developing cold- and drought-tolerant lines and hybrids with significantly enhanced yield potential.

Pigeonpea Hybrids

Pigeonpea is predominantly a self-pollinated legume crop, and most farmers grow pure-line varieties and landraces. Using partial natural out-

crossing and genetic male sterility systems, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has done pioneering research on pigeonpea hybrids by developing high-yielding, widely adapted hybrids as well as commercial seed production. The short-duration ICPHS has recorded 40 to 50 percent more yield than existing commercial varieties and has exhibited vigorous growth and yield stability. Hybrid pigeonpea in the farmers' fields provides yields of 2.5 to 3.0 ton/ha under single cropping and 1.7 to 2.2 ton/ha when intercropped with cotton. Private and public seed companies in India have already started marketing hybrid pigeonpea seeds. The companies' trained contract seed growers harvest 1 to 1.5 ton/ha of the hybrid seed (ICRISAT 1989).

Development of short-season (130 days) varieties permits farmers to use double-cropping intensities, whereas earlier varieties took over 250 days to mature. Similarly, pigeonpea varieties suitable for ratooning appear very suitable for sloping, fragile, and labor-scarce areas in Africa.

Chickpea

In the Mediterranean climates of West Asia and North Africa, ascochyta blight resistant varieties have been developed by ICARDA and ICRISAT. They are planted at the start of rains in November to make full use of the limited moisture. The winter-planted chickpea yields two to three times higher than the spring-planted local cultivars. This winter-planting technology for chickpea is rapidly spreading in Middle Eastern and North African countries.

Chickpea varieties such as ICC488201 and ICC488202 grown in fields with residual moisture have provided yields of 1 ton/ha in 90 days and are becoming popular in drought-prone environments in India because they mature early. ICRISAT scientists have succeeded in combining good yield capabilities for late-sown conditions after a monsoon crop and resistance to diseases such as wilt, ascochyta blight, and stunt, as well as to the pod-boring insects (ICRISAT 1989).

Cowpea

Cowpea is a major food legume in Africa and is also extensively cultivated in the lowland tropics of Asia and Latin America. It is a secondary crop mainly in semiarid ecologies, in association with millet, sorghum, maize, cassava, and cotton. It is drought-tolerant and can be grown in poor soil. In the mixed farming systems of the Sahelian regions, cowpea is the predominant legume and is an important source of human food and fodder for cattle.

The dry grain yields of traditional varieties have been low. In Africa, yields are estimated at about 250 to 300 kg/ha and in Asia and Latin America about 400 to 500 kg/ha. The low yields are generally attributed to poor crop husbandry, insect pests and diseases, drought, and unimproved varieties. Cowpea harvested as green pods in the lowland humid tropics yields from 10 to 15 ton/ha. In the Sahel, green fodder yields about 30 to 40 ton/ha or 3 to 4 ton/ha dry weight.

The International Institute of Tropical Agriculture (IITA) has succeeded in developing several lines of high-yield potential cowpea (2,000 kg per ha) with multiple virus, disease, and insect resistance (IITA 1989). The improved varieties require less spraying with insecticides because of their short duration and partial resistance. Earlier, cowpea was not a popular crop in the high-rainfall areas of West and Central Africa. With the availability of improved, more versatile varieties, it is now possible to grow the crop successfully in these zones as well. Short-duration cowpea that is suitable for cultivation in the humid zone during the short rainy season or during the dry season in paddy rice fallow has been developed.

Potato

Potato has secured a very favorable position in today's agriculture, indicating an even greater role that the crop could play in meeting tomorrow's food needs. The production of virus-free seed potatoes is important and has led the Netherlands to develop a seed potato industry for the export market. In the Netherlands, significant yield increases in the past 30 years have been achieved as a result of the introduction of new varieties and better techniques for Phytophthora control. However, relatively little progress has been made in conventional potato breeding in the last 50 years. Simmonds (1960) attributes this slow progress to narrowness of the genetic base of potato cultivars and further reductions in variation because of diseases.

Research support for potato production in the warm tropics is recent, yet results are encouraging. Tissue culture technology, easy to use with potato, is just beginning to be available. Information on hybrid varieties grown from true seed indicates that this technology may become a breakthrough in potato improvement and may greatly influence potato production by the middle of this decade.

Cassava

Africa accounts for well over half of global cassava area. In experimental fields, yields up to 20 to 40 ton/ha are easily obtained, compared with a poor 8 to 9 ton/ha in farmers' fields, highlighting the unexploited potential for cassava production (IITA 1989). Over the past two decades, considerable research effort has focused on cassava improvement, resulting in the development of high-yielding pest-tolerant cassava varieties. The gains from this technology, however, have been slow and limited. Diseases, pests, and location-specific problems remain major constraints to cassava yield increases.

If used, the available pipeline technologies have the potential to increase cassava yields in the 1990s. These technologies include varieties with better resistance to a broad range of pathogens; suitability for specific agroclimatic conditions; control of major pests through integrated biological techniques; methods to improve the quality and treatment of planting materials to reduce diseases, poor germination, and labor requirements; and postharvest and processing methodologies (Winrock report 1989).

Oil Crops

Vegetable oils account for about 70 percent of the world's edible fat production. The production of edible oils has increased steadily, but their production in many developing countries, including China and India, is inadequate to meet their demand. In the last decade, there has been considerable improvement in yield enhancement as well as in production and processing technologies, especially with sunflower, rapeseed and mustard, safflower, castor seed, and oilpalms.

Sunflower

Sunflower cultivation is rapidly growing in both developed and developing countries. As a result of plant breeding, oil content improved from 33 percent in the 1920s to more than 50 percent after World War II. With the availability of cytoplasmic male sterility and fertility restorer genes, hybrid sunflower has become very profitable in the last two decades. Large areas are now under hybrids in the U.S.S.R., the United States, Europe, Australia, Canada, and in many developing countries in Asia, Latin America, and Africa. The sunflower is the first major oil crop to join the list of crops in which heterosis is being exploited through the use of F1 hybrids (Sneep, Murty, and Utz 1979). Development of both open-pollinated varieties and hybrids is actively in progress, and the 1990s may see higher-yielding

lines and hybrids and further expansion in the sunflower area. Open-pollinated varieties are still of interest in drier and lower-input areas, whereas hybrids are more suitable for moderate and high-resource base areas.

Other Oil Crops

A hybrid, *Brassica napus*, developed by Niu and Zhao at Hefei Research Station in Anhui province of China, has provided average yields of over 3.5 ton/ha in large areas. Presently it occupies over half a million hectares in China and is fast spreading. Oil radish (*Rhaphanus raphanistreroides*) is one of the main oilseeds grown in southwestern China. It has annual as well as biennial forms, is tolerant to low temperatures and drought, and grows well on acidic and alkaline soils. Oil content is up to 52 percent, compared with 40 percent in *Brassica* oil crops, and the oil is of excellent cooking quality and is low in glucosinates. High yields have been reported for several crops: 5.8 ton/ha in groundnut in Israel; 2.8 ton/ha in rapeseed in Germany; 2.2 ton/ha in sunflower in Italy; 2.0 ton/ha of sesame in Yugoslavia; and 2.0 ton/ha in linseed in New Zealand. With oil palm, the employment of tissue culture techniques has started to pay off. During the 1990s, use of higher-yielding varieties and hybrids will further enhance yield potential of vegetable oils.

Cotton

There has been steady progress in the improvement of cotton yields; however, progress through conventional breeding has slowed. India has made remarkable progress in cotton production in the last 10 years through the use of hybrid cotton technology. Hand-pollinated hybrid varieties were first released in the 1970s and now occupy 28 percent of cotton area with 40 percent of the national production. During the 1980s the hybrids played a major role in both qualitative and quantitative improvement of cotton and will play a greater role in the 1990s as new hybrids cover additional land. It is interesting to note that 70 percent of cotton is produced from rainfed areas where hybrids have enhanced yield and production. There may be further improvements in hybrid cotton technology that will spread to other countries.

Other Crops

Tables 1 and 6 illustrate production of major commodities in the second half of the 20th century. There has also been progress in development of high-yielding fodder crops such as sorghum--sudan grass, pearl millet--napier hybrids, and cold-tolerant medics that will provide increased biomass for animal production. Hybrid vegetable seeds are slowly revolutionizing vegetable production, and the ornamental crop industry has greatly benefited from new technologies. Hybrid eucalyptus trees have enhanced rapid biomass production, and during the 1990s there will probably be greater use of hybrid vigor technology in fruit and tree crops.

Table 6. Production of Major Commodities, 1988
(million metric tons of cereal equivalent)

Region	Total cereals	Growth rate 1961-88	Roots and tubers	Growth rate 1961-88	Pulses	Growth rate 1961-88	Banana and Plantain	Growth rate 1961-88
World	1,646.2	2.74	136.4	0.95	54.6	0.58	12.9	2.36
Asia	637.4	3.63	56.4	2.26	19.9	-0.22	3.8	3.64
W. Africa/ Middle East	84.8	2.49	2.4	4.96	4.4	2.77	0.1	3.40
Sub-Saharan Africa	51.4	1.74	26.1	2.39	5.4	1.86	4.5	2.33
Latin America	103.8	3.17	12.2	0.52	5.7	1.08	4.4	1.57

Source: Facts and Figures, International Agricultural Research 1990.

Emerging Technologies

During the 1990s we must prepare for the 21st century, which will be characterized by significantly increased demand for food, fiber, and fuel and decreased availability of land, water, and energy to produce them. The main challenge will be to develop technologies that will produce more from fewer resources. Ruttan (1989) has summarized the role of conventional technologies:

- Advances in conventional technology will remain the primary source of growth in crop and animal production over the next quarter century;
- Advances in conventional technology will be inadequate to sustain the demands that will be placed on agriculture as we move into the second decade of the next century and beyond;
- There are substantial possibilities for developing sustainable agricultural production systems in a number of fragile resource areas.

Biotechnology

Expectations from plant genetic manipulations at the molecular level are as great as or greater than those achieved through Mendelian genetics earlier in this century. The development of saturated genome maps and the identification of molecular markers associated with genes modifying adaptation, biotic and abiotic stress tolerance, crop quality, disease and pest resistance, and plant development currently consume a significant amount of the total crop genetics research resource base. The development of cultivars adapted to integrated cropping systems and more efficient utilization of natural resources will depend upon the aggressive integration of classical plant breeding and agronomy with the most effective tools provided by biotechnology and crop modeling. Although this is not a simple, one-step solution to crop production problems in developing countries, it might provide a flexible approach to resource development and utilization that would be practical in a 20-year time frame.

Although the technology holds considerable promise, achievement so far has been in the development of herbicide and disease-resistant varieties in a few crops and rapid virus detection kits. Developments in successful transformation technology need further research before their feasibility and potential value can be assessed.

The technology of cell and tissue culture is gaining increasing importance in plant breeding and production. These procedures are being used to develop plants from anther culture to rapidly multiply new genotypes by micropropagation and to potentially produce hybrid genotypes by means of protoplast fusion and generation (Riley 1977). The new tools provided by biotechnology research will increase the efficiency, reduce costs, and speed the rate of crop improvement, but they will not replace many conventional plant breeding procedures.

Biological Nitrogen Fixation

Although symbiotic nitrogen fixation has been studied for almost a century, only recently has there been a rapid increase in our understanding of the process. Identification of more efficient rhizobium strains for specific crop variety and location has been possible and used. In the future, it may be possible to incorporate in the cells of nonleguminous crops alien DNA carrying the information for nitrogen fixation, although it will not be easy. In the meantime, researchers are working on identifying and developing nitrogen-efficient cultivars; enhancing nitrogen-fixing properties of legumes through rhizobia; increasing effectiveness of blue algae fern and azola;

ascertaining more efficient nutrient use and recycling; studying the use of crop residues and green manures as sources of nitrogen fertilizer; and studying the use of forage legumes, crop rotations, and sequencing to enhance soil fertility. These practices could be more effectively used in the 1990s.

Satellite Imaging

Valuable information about weather, natural vegetation, soils, and forestry conditions is becoming increasingly available through satellite imaging. The products of this new technology can help in monitoring crop growth, disease and insect pest development, and natural resources availability and use, and they can predict potentially hazardous conditions to allow for remedial action (Brady 1989). Several systems are already available on the Geographic Information System (GIS), which provides integrated information.

Crop Simulation Models

Crop simulation modeling is another recently developed tool that is proving useful in many countries. By combining soil classifications along with crop, water, weather, pests, and management practice information in computer simulations, crop yields and suitability can be predicted. This will identify optimum land use combinations for given locations in a fast and cost-effective manner. During the 1990s greater use will be made of crop simulation technology to provide more detailed analysis and to match crop climatic and soil requirements with site characteristics.

Integrated Pest Management

An important approach to sustain and increase production is to protect crops from the pests and weeds that cause significant yield losses in different agroecosystems. However, crop protection can have adverse economic, environmental, and health consequences if inappropriate control measures are used. Considerable progress has been made in developing and stressing the use of integrated pest management systems utilizing a thorough knowledge of the key biological interactions for specific agroecologies that will have comparative advantage over the long term. Greater use of this emerging technology is expected during the 1990s and into the next century.

Agricultural/Crop Diversification

Mixed farming, which has been a way of life for farmers, was replaced by mechanized monocrop culture as a "modern technology" in most developed and many developing countries. However, agricultural diversification will assume greater importance in the developing countries (Barghouti et al. 1990). Integrated crop-livestock-agroforestry farming systems will provide greater resource utilization, income, and risk aversion, particularly in the rainfed areas. Alternative cropping strategies; crop rescue techniques; and multiple, mixed, and alley cropping systems will become more useful to suit different weather models. Postharvest technology should receive much more attention so that both farmer and consumer can derive full benefit from the products. The world is relying on a few species to meet its food requirements, thus exposing itself to risks. The potential of some of the underutilized plants, e.g., finger millets, amaranthus, Chenopodium species, vetiver grass, lathyrus, and triticale, should be maximized rather than expanding the area of only a few crops.

Hybrid Vigor

Given the success of hybrid technology in food crops, vegetables, ornamentals, and trees, its use will continue to increase during the 1990s. The current techniques will be further refined and extended to new crops. When cytoplasmic male sterility and/or fertility-restoring genes are not feasible, chemical substances will be utilized to produce hybrid seeds. This

decade will see strong emergence of the private sector seed industry and maximum exploitation of hybrid seed technology for increased food production.

Technologies for Resource-Limited Base Areas

So far increases in production have come primarily from employment of improved technologies in the high-resource base areas. As indicated earlier, the scope of expansion in such areas is limited. Therefore, the challenge for the 1990s and the 21st century will be to improve productivity in less-favored areas. To sustain and increase production from such areas, it would be important to identify major abiotic, biotic, and management factors imposing productivity restrictions. For example, it is possible to develop genotypes that will tolerate low or high temperatures, such as cold-temperature sorghum, wheat, chickpea, and medics (or potato for warm tropics) or incorporate mild vernal genes in wheat to delay early flowering caused by high temperature. Examples include wheat and maize cultivars that can tolerate aluminum toxicity in the soil; early maturing varieties to match available moisture in dry areas; and tricale for acidic soil, barley for salty areas, and improved forage legumes and biennial pigeonpea for sloping and marginal lands. Use of heterosis in many crops seems to improve yields from less-endowed areas.

Productivity will be improved by use of adapted crops; use of integrated crop-livestock agroforestry farming systems; improved soil, water, and nutrient management; and crop rotations and sequencing (table 7). Use of environmentally controlled culture, such as plastic houses, will further enhance productivity from limited natural resources. The RFLP technology has started to provide more precise information on the location of genes and markers on chromosomes controlling specific characters. This information will improve and accelerate the germplasm development with specific resistance that will improve productivity from the currently underutilized areas.

Table 7. Grain Yields under Improved and Traditional Varieties on Deep Vertisols at ICRISAT, Hyderabad, India (t/ha)

Year	Cropping period rainfall	Grain yield				
		Improved systems: Double cropping			Traditional systems: Single crop	
		Sorghum/ maize	Sequential chickpea/ pigeonpea	Total	Sorghum	Chickpea
1976/77	708	3.20	0.72	3.92	0.44	0.54
1981/82	1,073	3.19	1.05	4.24	0.64	1.05
1986/87	585	4.45	0.38	4.83	0.37	1.27
1988/89	907	4.64	1.23	5.87	0.61	1.18

Source: Swaminathan 1990.

The most immediate and significant improvements in dryland crop production will result from improved management practices. Whitman and Meyer (1990) suggest following examples of agronomic practices that could bring positive results in many dryland areas: weed control; improved crop geometry and population rates; improved crop calendars linked to seasonal precipitation probabilities; runoff-reducing practices; conservation bench terracing and mechanical and vegetative bunding; maintenance of soil cover; water-harvesting systems; improved tillage systems, including minimum, ridge, or no till;

improved fertility practices; and improved forage/livestock systems, including forage legumes. Choice of crops and recommended varieties matching the agroecosystems along with appropriate agronomic practices will synergize the use of available resources in drylands.

Conclusion

Anderson and Herdt (1989) appear rather pessimistic about the ability of current technologies to advance yield levels in the developing countries. They believe that yield increases from rainfed areas through maize, sorghum, and millet technologies will take quite some time to develop, and they express some uncertainty about biotechnology's promise. However, the conclusion of this paper is cautiously optimistic. Suitable genetic materials currently exist for most of the crops to induce substantial gains in productivity when grown in conjunction with appropriate agronomic practices. It is possible to obtain increased and sustainable yields both from high- as well as limited-resource base sectors. However, more efficient and productive genotypes and crop husbandry will be required to meet the agricultural needs of the 21st century.

Acknowledgments

This paper incorporates published and unpublished material from a large number of sources. Linda Nodine did the arduous and painstaking work of compiling and organizing reference material, preparing graphs and tables, and providing finishing touches to the paper. I am also grateful to Anthony J. Pritchard for his helpful comments and suggestions during the preparation of the manuscript.

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SESSION III:
PERSPECTIVES ON THE GATT NEGOTIATIONS

policies and practices, much more difficult to master than knowledge of customs regulations. The new Trade Policy Review Mechanism does little to fill this gap. Moreover, these new concerns touch upon areas where not only central governments, but also state and local governments intervene.

They also involve ministries that traditionally do not participate much in trade negotiations. They sometimes view with concern the efforts of their colleagues from what is, generally, a junior ministry to bring under scrutiny and discuss with foreigners regulatory and other processes in fields they had long considered their exclusive domain. The prospect of having to subject their dealings with financial service providers to the review of a motley group of foreigners is viewed, by officials from the French Ministère des Finances, Japan's Ministry of Finance, or the U.S. Treasury, with enthusiasm that can, at best, be described as moderate.

Add to all this the normal protectionist resistance of activities that often were not even exposed to full national, let alone international, competition before: banking, coastal shipping, insurance, airlines....No wonder there seem to be few areas where any national delegation views with great enthusiasm the agreements that, technically, may be within reach.

Agriculture, however, is clearly the most sensitive area politically. Although a complex field, it is simple in at least one respect: whereas conflicts in many other areas cannot be classified along "free trade" or "protectionist" lines, in agriculture they can be so classified with little difficulty.

At the free trading end is the Cairns Group of agricultural exporters, from Argentina and Australia through Hungary to Uruguay. Very close to its positions, and in a way swamping the group by its size, are the United States and, with minor variants, Canada. Then, quite far away come the European Communities (EC). Farther still stand most other European countries, Japan, and Korea; these countries do not seek prominence in the negotiations and may have difficulty holding out against a U.S.-EC agreement.

Several major developing countries still want exemption from most clauses of a binding agreement. There is also a group of food-importing developing countries concerned that liberalization would raise their food import costs by reducing subsidies. They seek "compensation." Indeed, one of the Brussels Conference's eerier moments came, at a time failure was already patent, when a distinguished delegate devoted a large part of his speech to a plea for compensation in the face of the sharp rise of agricultural prices to be provoked by looming liberalization.

The U.S. position aims to reduce agricultural protection to broadly the same level as protection for manufactures. Concretely, the United States proposes a 75 percent reduction in the Aggregate Measure of Support over 10 years, although certain income support measures are excluded. Export subsidies, undoubtedly the most disruptive form of intervention, should be reduced by 90 percent over the same period.

The EC, by contrast, offered a 30 percent reduction in overall support. They also proposed raising the protection offered to some commodities: this is "rebalancing." The base year is 1986 both for starting the 10-year countdown and for reducing the support level. As current support is lower, this would mean roughly 4 percent annual reduction from 1991 through 1996. No specific commitment has been offered on export subsidies, although the EC has proposed to "illustrate" the impact of its overall proposal on them. In the language of diplomacy, this signals a willingness to negotiate within a given framework.

A noteworthy feature of this proposal is that (with certain qualifications) it is formulated in current prices. Given projected ECU inflation rates, the proposed support reduction until 1996 would amount to

SUMMARY OF THE RESULTS OF THE URUGUAY ROUND NEGOTIATIONS

Jean Baneth

I was asked to describe to you in detail the results of the Uruguay Round trade negotiations....I just did.

Having thus dealt with my assigned topic, I will give you some of the background concerning the Uruguay Round overall, though, of course, with particular attention to agriculture.

Trade barriers have been lowered in the framework of the GATT several times through a series of concentrated, time-bound multilateral negotiations. These are called "rounds," just as in boxing: Dillon, Kennedy, Tokyo, Uruguay Round. The negotiations are multilateral and based on the most favored nation (MFN) rule: any concession to one participant applies to all.

The "concession" principle is itself a basis of the GATT and indeed of all trade negotiations: notwithstanding economists' claims that free trade benefits the practitioner, trade negotiators make a "concession" when they lower barriers. This, incidentally, greatly reduces the negotiating weight of an open economy such as Hong Kong.

Earlier rounds have succeeded in greatly lowering tariffs of industrial countries on most manufactures. The Uruguay Round therefore set out in new directions. It aimed to:

- cover previously excluded goods (agriculture, textiles and clothing);
- cover services;
- cover (and regulate) measures deemed to have an impact on trade, though not necessarily at borders: investment measures, subsidies, and the treatment of intellectual property (TRIMS, TRIPS);
- improve the functioning of the GATT system (FOGS), notably its dispute settlement mechanism; eliminate grey area measures by either explicitly forbidding them or allowing and regulating them (this applies, in particular, to dumping and antidumping);
- obligate member countries that have thus far undertaken few obligations (mostly developing countries) to do so now.

Agriculture is both the subject of the present symposium and the main point of contention. However, it is not the only unsettled issue by any means. Without analyzing the state of the negotiations in any detail, I will say that in several areas the prospects of precise, detailed, binding agreement seem remote. However, as the public debate surrounding these areas has been quite muted, loosely worded agreements that would postpone the resolution of key issues could perhaps be negotiated if a highly satisfactory accord were reached in agriculture.

The novel features of the Uruguay Round have caused negotiations to cover areas traditionally considered relevant only domestically. This jars old habits. It also requires familiarity with other countries' domestic

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about 7 to 8 percent annually in real terms, rather than 4 percent. Even if no further reduction were undertaken, support would continue to be reduced in real terms.

The qualification is contained in separate provisions for compensatory levies if world prices fall below their base year reference levels. These compensations are partial and progressive if the fall relates directly to commodity market movements; they are total if the fall is the result of exchange rate movements. This is not a transition measure; it is permanent. The reference price, however, is to be defined in current ECUs.

Behind these divergent offers rest deep philosophical differences in the desired final shape of world agriculture. The Cairns Group and the United States ostensibly aspire to completely free trade and free agricultural markets, with no government intervention except for consumer and environmental protection and for health- and phytosanitary-related reasons.

The EC ideal appears to be a more organized market, not really insulated from supply and demand factors but certainly cushioned from their variations. All EC members (except, perhaps, the United Kingdom) back this position, but what this market organization may consist of and how it would function have not been defined. Once they are, it may well prove to be more contentious. The EC has broad consensus on the philosophical-political bases of the desired social market economy in agriculture, but no consensus, nor even a firm view, on its concrete shape.

Conversely, in the United States, there seems to be broad consensus favoring free market ideology, but there is by no means agreement on its concrete application to agriculture, particularly under reasonable assumptions concerning what trade partners might be willing to concede for the sake of a trade agreement. The United States has a consensus of sorts on what it views as the most desirable outcome, but that is unattainable. It has no consensus on how to array, from least to most desirable, the potentially attainable outcomes of partial liberalization.

These are not favorable conditions for the "give and take" of negotiations, especially because the other negotiations are creating no overwhelming pressure for agreement. Few of the agreements that seem within reach are viewed by any major partner as highly attractive--worth a high price in terms of agricultural "concessions."

There is also a lack of confidence that, should an agreement be reached, the U.S. Congress would necessarily ratify it in sufficiently binding form both to protect it from unilateral reversal and to impose it on state and local governments (which may well be needed in areas such as TRIMS and subsidies, e.g., irrigation water charges). As for the EC Commission, its ability to obtain the ratification of agreements it signs is undoubted, but it pays a price in prior consultations, which greatly limits its ability to modify formal proposals it has made. These unfavorable conditions for negotiations are illustrated by events at Brussels, where a deadlock developed so rapidly that, by the morning of the fourth day of negotiations (scheduled to last six or even seven days) I telegraphed Bank headquarters, quoting the telegraph received by Emperor Franz-Josef after the battle of Sadowa: "Predicted catastrophe arrived complete." The negotiators nursed their misery for another day, but their hearts were not in it.

Now what? The same considerations hold. Trade negotiations resume on January 15. That date is also mentioned in another context, which not only impels major participants to avoid acrimonious dissensions (not necessarily noticed in the tone of some public pronouncements) but also deflects attention from trade. Even if matters are settled in the Persian Gulf at the fastest conceivable pace, and if high-level attention refocuses on the Uruguay Round, all outstanding issues cannot be resolved in time for a detailed legal document to be submitted to the U.S. Congress before the end of

next month (the last date compatible with the present "fast track" legislative authority). In other words, a happy conclusion of the Uruguay Round within the original time frame seems quite unlikely.

A failure would not abrogate previous treaties and arrangements, under which, after all, trade has fared well. Press reports notwithstanding, no imminent threat of a trade war looms, nor does a sense of "being left hanging."

There will not be a full-scale trade war, but a cold war, with attendant skirmishes: further erosion of the rules, further spread of bilateral negotiations and unilateral restrictions, further misuse of antidumping measures, and further uncertainty to deter investment.

Then, as mounting costs are felt, a new effort to reach agreement may occur, this time successfully. One, two, or perhaps five years or more of growth opportunities would have been lost. This is a disproportionately high cost to pay for agriculture, 2 percent of the industrial countries' GDP at artificially high domestic market prices.

In agriculture itself, with or without GATT agreement, the momentum for reform is irresistible. An increasing number of people are convinced that subsidies that artificially boost the use of fertilizer and pesticides that then pollute scarce water resources may, on balance, constitute a somewhat inefficient use of consumers' and taxpayers' monies.

Policies will change, both in Europe and the United States. Support payments will be geared more closely to income support (as opposed to input use), and perhaps also to specific services demanded in return. First, though, one must define more precisely the types of agriculture and the sorts of countryside desired by society--and that is still a long way off.

So although reform is undoubtedly coming, it may be tentative and slow. Prudent, gradual progress may be appropriate in such a delicate field, yet success in dealing with excess agricultural production should not come only when acute global food shortage becomes the problem of the day.

THE GATT AND THE EUROPEAN COMMUNITY'S AGRICULTURAL POLICY

Jacques Vonthron

This presentation first examines the Uruguay Round--the present round of multilateral trade negotiations--and its status since the Ministerial Meeting last December in Brussels. The question of and the need for reform of the common agricultural policy are then discussed. The presentation concludes with a brief, broad overview of the economic and commercial dimensions of the European Community.

The Uruguay Round

The Uruguay Round is not the first multilateral trade negotiation to have been conducted under GATT auspices, but it is the most ambitious in its attempt to cover virtually all aspects of international trade, from trade in goods to services and intellectual property rights. Nor is it the first negotiation to have tackled agriculture, but it is certainly the first time that agricultural support and protection have been given so much prominence in a trade negotiation. This may seem surprising in view of the relatively small share of agriculture in total world trade, but it reveals the difficulties on world markets, increased competition, and growing budgetary problems experienced by some important trading partners (on both sides of the Atlantic).

After four years of international negotiation, and the failure in December 1990 of what was supposed to be the final Ministerial Conference in Brussels, it may be useful to draw lessons from the latest negotiations. In agriculture, the task undertaken by GATT was both unprecedented and necessary. In Punta del Este in September 1986, all participants could not but agree on the global objective of the negotiation: to "reduce the uncertainty, imbalances, and instability in world agricultural markets."

Later, in Geneva in April 1989, there was also a consensus on the need to initiate a reform process through the negotiation of commitments on support and protection. The European Community fully subscribed to such objectives and shared the general diagnosis of the situation, pointing out in its proposal of December 1989 that "agricultural policies have, over the years, developed support mechanisms including high levels of protection which have resulted in an unreasonable attenuation of the relationship which should exist between production and the markets."

Why then has the process been so slow? Why has there been cause, at times, to talk about deadlock in these negotiations? The first reason involves the complexity of the technical discussions. Because of the large variety of support systems throughout the world, it was essential to agree on a yardstick with which to measure the level of support in different countries. Other reasons for delay and ultimate deadlock were of a more ideological nature. Very early in the negotiation, it became clear that for partners such as the United States and the Cairns Group, trade liberalization meant putting an end to the special treatment of agriculture in the present GATT rules, whereas the Community was (and is) firmly attached to the recognition of the specific character of agriculture production and trade.

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Deadlock was even more predictable when the negotiating position of certain participants clearly targeted the EC's specific support mechanism of the dual-price system and its related measurements at the border (i.e., variable levies and export refunds). The negotiation process finally broke up in December 1990 because expectations of certain partners were too high.

How do we move forward? Participants in the Uruguay Round negotiations have just agreed "to conduct negotiations to achieve specific binding commitments in each of the following areas: domestic support, market access, export competition." On that basis, the Bush administration has requested Congress to extend the so-called fast track authority, an indispensable procedural instrument for U.S. negotiators that commits Congress to approve or reject the final result of the Round in one vote, with no amendments.

This extension of the negotiating period should now be used first to complete the technical work--or to be more precise, the analytical work--that should have been done before the Brussels Ministerial conference and to tackle the real political issues with all necessary realism and pragmatism. Realism means that "the aim of the negotiation can only be to progressively reduce support to the extent necessary to reestablish balanced markets and a more market-oriented agricultural trading system" [from the EC's December 1989 proposal]).

The rate of reduction of support must be reasonable and consider its social impact. The duration of the reform period must be such to provide a sufficient transition period. To ensure that real trade liberalization is achieved, specific commitments will be taken in all three areas mentioned above. In fact, there never was any doubt that this would be the case. The question is through what process such commitments will be reached, whether independently or relatedly. In the European Community's view the commitments in the three areas have to be related, because commitments on border measures, both on imports and on exports, are being inextricably linked to the targets for the reduction in internal support. A demonstration of the European Community's readiness to enter into such specific commitments was provided at the Brussels Ministerial conference, notably on minimum market access and on exports benefiting from restitutions. Realism will also have to be shown in tackling, in concrete terms, the question of special and differential treatment for developing countries.

Finally, the GATT rules and disciplines will have to be reinforced. The objective, however, is not to impose on agriculture the uniform treatment being devised for trade in industrial goods, thus ignoring its specificity.

Realism and a sense of fairness will prevail because we cannot allow ourselves to fail. In this case, the reform efforts undertaken in many corners of the world (in the United States with the new 1990 farm bill, in Canada, in the EC [as presently proposed by the Commission], and also in other parts of the world) will be accorded both their necessary recognition and encouragement to the benefit of all trading partners and, in the final analysis, to the benefit of agriculture itself. Before dealing with the reorientation of the European Community farm policy (or CAP), I will discuss a few items, often forgotten, but central to the European agricultural economies. They pertain to EC agricultural trade and to EC commodities prices.

On the question of agricultural trade, the Community is by far the world's largest importer of agricultural produce and foodstuffs: in 1987 it imported the equivalent of 23 percent of world agricultural trade (United States, 13 percent; Japan, just over 10 percent). Moreover, the European Communities imports large quantities of agricultural goods of which it has a surplus (e.g., sugar, beef/veal, cereals). The overall agricultural trade deficit was over \$27 billion in 1988 and has increased in recent years.

Moreover, 55 percent of EC agricultural imports enter duty free. EC guaranteed agricultural prices have been drastically reduced over the last several years and have triggered cuts in agricultural production. For the last six years the European Communities has applied to the sector a restrictive price policy. Since 1984, cereal prices have fallen in real terms by about 30 percent, oils/oil fats by 27 percent, beef/veal by 20 percent, and sugar and milk by about 14 percent (an average fall of 19 percent over 1984-89). The EC's measures have contributed to an easing of international trade problems, particularly for products for which the Community has a large share in international trade. The reduction of community stocks up to the end of last year, linked with the policy of controlling production, has influenced the world market favorably and made a decisive contribution to the spectacular recovery in world prices. This production stabilization program, coupled with ever diminishing prices, had dire consequences for the income of many farmers.

After two years of relative calm the agricultural situation in the Community has recently deteriorated. Several commodity markets are again well out of balance or threaten to become so rapidly, and budget expenditure is rising sharply. In major commodity sectors (beef, dairy produce, cereals), public stocks are again on the increase and in some instances are reaching record levels. At the same time the latest budget estimates indicate that farm spending could increase this year by a third compared with last year if no corrective action is taken. Similar situations have arisen on this side of the Atlantic where last year's budget cuts have been overwhelmed by an unbalanced world market situation.

The rapidity of recent market developments has convinced the EC Commission that, apart from short-term action to stabilize the situation, a fundamental change of direction in the common agricultural policy is essential. The results of this exercise were presented by the European Commission in its reflection paper on the development and the future of the CAP in January 1991.

The Need for Reorientation of the Common Agricultural Policy (CAP)

The CAP has sometimes been presented as a victim of its own success. In fact, a policy based primarily on price supports to stimulate production and protect farmers' incomes was well adapted to the situation of the 1960s and 1970s, when the Community was in deficit for foodstuffs. But now three major reasons have necessitated a reform of the policy.

First, the guaranteed price levels have encouraged production at a pace that increasingly has outstripped the market's capacity to absorb: between 1973 and 1988 the volume of agricultural production in the Community increased 2 percent per year, whereas internal consumption only grew by 0.5 percent per year. There was a costly buildup of stocks (valued at 3.7 billion ECU in the 1991 budget). An increasing number of products had to find an outlet on the world market, leading at times to friction with the Community's trading partners, some of whom were engaged in heavily supporting agriculture and also confronting surplus and budget problems.

A second problem of the CAP, where support is largely proportionate to the quantity produced, is the built-in incentive of intensification of production with possible adverse effects on the environment. Third, a support system based on price guarantees and therefore closely related to the volume of production tends to concentrate the greater part of support on the largest and most intensive farms. Moreover, whereas the agricultural budget has more than doubled in real terms since 1975, per capita purchasing power in the agricultural community has only risen slightly, despite the Community's active agricultural population (currently 11 million farmers) having fallen by 35 percent over the same period. These different elements have led the EC to redefine the objectives of the Community's agricultural policy and the guidelines that should influence the future development of the policy.

Objectives

The central aim of the EC Commission when it formulated this policy reorientation was to keep a sufficiently large number of farmers on the land with a decent income to maintain the social fabric of rural areas, to protect the environment and the countryside, and to develop a quality-based production geared to demand.

It is important to recognize the dual role the farmer fulfills as producer of food and raw materials and as well as guardian of the countryside. Farming has traditionally focused on production of food and will continue to do so, although a growing emphasis will be placed on supplying raw materials for nonfood uses. Concern for the environment means that less intensive techniques must be encouraged and that environmentally friendly measures should be developed.

The European Community also recognizes the existence of international interdependence and accepts its responsibilities as the leading world importer and second-leading exporter of agricultural products. It will remain active on the world market regarding both imports and exports through a policy encouraging a competitive and efficient agriculture.

Instruments

Currently, detailed reform proposals are still being studied, but a general framework indicating the broad lines of the reorientation of the CAP has been developed. A two-stage approach has been chosen, centering on the market policy for the crop and livestock sectors on the one hand, and on environmental and sociostructural measures on the other. Although the traditional instruments of price policy and quantitative controls will continue to have a central role in the attainment of market balance, the farm programs should also encourage extensification with the dual object of reducing surplus production and contributing to an environmentally sustainable form of agricultural production.

In addition, support to farm incomes should be redirected so that they do not relate almost exclusively to market price guarantees. Direct income aid measures could be differentiated according to different factors. In the same manner where quantitative arrangements apply or may be brought into effect (quotas, temporary fallow, etc.), the corrective measures needed could be related to the economic circumstances of the farmers or regions concerned.

For the Community's trading partners the reorientation of the CAP should lead to a more dynamic and cost-efficient European agriculture, focused on more direct contributions to farmers' incomes. The progressive switch to less intensive and more environmentally friendly farming practices should also contribute to greater market balance and stabilization of world markets.

Conclusion: Global Economic and Trade Dimensions of the EC

It is often said that the EC is a commercial power and is becoming an economic giant, but still lacks the befitting political dimension. This is true: the EC single-market program will one day--if not very soon--be "transformed" to yield to a economically and politically unified European Community.

The gross domestic product (GDP) of the twelve member states of the European Community represents about one-quarter of global GDP. The EC's external trade accounts for about one-fifth of the world total. So although the Community's economic performance relies largely on its internal dynamism, external trade is also a significant factor. About two-thirds of the Community's GDP arises from services, compared with one-third from industry and only 3 percent from agriculture, forestry, and fisheries. In 1989, EC

merchandise imports were ECU 429 billion, compared with ECU 392 billion for exports (deficit ECU 37 billion). As in the case of agricultural trade, the European Community is "import addicted": 81 percent of this trade is with GATT partners, the rest mainly trade with the U.S.S.R. and oil-exporting non-GATT members.

"External" trade is of vital importance to all EC member state economies, a major element of their GDP and a strong component of growth (or lack of it). This explains the Community's long-standing attachment to the multilateral system, which is viewed by far as the best means of ensuring the vigorous expansion of external trade and of protecting its interests worldwide.

A central objective of the EC's single-market program is trade liberalization. This coincides with the aims of the Uruguay Round, namely, to strengthen and maintain the multilateral trading system. The general economic effects of the 1992 single-market program are already visible in the transformation of the Community's economic performance, in particular the generation of additional growth by, among other things, increased efficiency and investment. Better economic performance and the removal of barriers will create much new trade and many investment opportunities for third countries; since 1985, EC manufactured imports from them have risen 34 percent. Thus the benefits of the single market have been transmitted to third countries.

The removal of the remaining controls on goods at internal borders, and of their costly and cumbersome procedures, will benefit third country exporters; for example, they will be subject to only one custom import procedure, after which they will circulate freely with no frontier control. The already very low weighted average of the EC tariff of 5.7 percent (unweighted average 6.5 percent) would be even further reduced by the EC's offer to 3.9 percent (4.6 percent) if the Uruguay Round negotiations are successfully concluded.

THE GATT AND AGRICULTURE

Bruce Gardner

Background on Negotiations

The April 1989 framework agreement in Geneva called for "substantial progressive reductions in agricultural support and protection, sustained over an agreed period of time, resulting in correcting and preventing restrictions and distortions in world agricultural markets." U.S. negotiators stated that "substantial progressive reductions" would ultimately lead to elimination of such support.

No one has ever doubted the extreme difficulty of placing world agriculture on a market basis. Clearly, the politics in many countries dictate assistance to agriculture. Recognition of the difficulties led the United States to propose separate disciplines for market access, export subsidies, and internal supports. It seems inevitable that some sort of internal support for farmers will be provided, so that internationally negotiating an abandonment of this support would be impossible. This leads to a position in which only trade-distorting support measures are considered and the retention of so-called "green" policies is permitted. The difficulties of specifying green policies, however, mean that whatever is done domestically must be subject to particular disciplines that open borders to imports and reduce subsidized exports.

The U.S. comprehensive proposal for agricultural trade reform in October 1989 covered:

- market access: convert all nontariff barriers to bound tariffs; make substantial cuts in these and existing tariffs over 10 years; use tariff rate quotas and safeguard measures to facilitate transition;
- export competition: phase out export subsidies over five years; prohibit export restrictions on foodstuffs imposed because of short domestic supplies;
- internal support: phase out most trade-distorting measures; discipline those that interfere less; permit those with small trade effect that meet specific criteria;
- sanitary and phytosanitary measures: place these under an international process for dispute settlement and harmonization.

Art De Zeeuw, chair of the Agricultural Negotiating Group, submitted a paper in early July 1990 that dealt with:

- internal support: price supports, deficiency payments, and input/marketing subsidies substantially reduced using an AMS; permitted programs subject to overall ceiling;
- market access: nontariff measures converted to tariffs and substantially/progressively reduced over a negotiated period of time; minimum access levels established; price/quantity-based import safeguards; "negotiate specific solutions in case of

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particular situations that may exist for some products" (rebalancing);

- export assistance: reduced more than other forms of support and protection; commitments to reduce budgetary outlays, per unit assistance, total quantity, or some combination;
- countries to submit country lists by October 1 dealing with internal support, tariffication, and export subsidies.

The economic summit in July 1990 supported the use of the De Zeeuw paper as a "means to intensify the negotiations." The U.S. proposal of October 15, 1990, based on the De Zeeuw paper, proposed:

- internal support: commodity-specific trade-distorting support reduced by 75 percent over 10 years based on an AMS (1986-88 base);
- market access: nontariff import barriers converted to tariffs and bound, existing tariffs bound, and all tariffs reduced by 75 percent over 10 years; minimum access based on tariff quotas for nontariff commodities to be expanded by 75 percent over 10 years;
- export assistance: export subsidies on primary products reduced by 90 percent over 10 years; on processed products, export subsidies phased out in six years.

Although the only sensible final objective of reforms is the elimination of trade-distorting support, export subsidies, and import barriers, the difficulties in achieving this create an approach that takes only the first steps on the path toward free trade. An agreement must place each country firmly on that path and not suggest that partial reforms ending in, for example, 1996 would be sufficient.

The commitment to such a path is a difficult one, even in exporting countries such as the United States, and is apparently nearly impossible in the European Community and Japan. Nonetheless, because all of the negotiating parties had signed on to the substantial progressive reduction formula in April 1989 and had reaffirmed this last summer, there was hope that this position could be formally ratified in terms of a GATT agreement in Brussels.

The EC proposal of November 7, however, generally ignored the framework of De Zeeuw's text. It proposed:

- internal support: 30 percent cut in AMS for major commodities over 1986-96; 10 percent cut for other commodities;
- market access: The EC intended to maintain a tariff wall that is prohibitive of imports over the period of the agreement; this is accomplished through the "community preference" provision and boosting of the base calculations so that the 1986 wall is much higher than necessary to keep imports out. Then, exchange rate adjustment and a corrective factor in response to world price movements would be sufficient to prevent the tariff wall being lowered enough to let any imports in under any plausible world price scenario for the 1991-96 period. Moreover, this change, which accomplishes nothing in market access, is accompanied by a proposal for rebalancing that would set the maximum level for oilseed products and nongrain feed ingredients at the average level of imports during 1986-88. In addition, a tariff rate of 6 or 12 percent (depending on the commodity) would be introduced for

these commodities. Thus, the EC proposal actually provides less market access than is currently provided;

- export subsidies: no specific commitments.

Brussels Ministerial

At the opening of the Brussels Ministerial (December 3-7, 1990), Ambassador Hills restated the U.S. position that success in the Uruguay Round encompasses fundamental reform of world agricultural trade.

During the Brussels meetings, the EC offered the following concessions:

- The volume of subsidized exports would be frozen and then gradually reduced (but with no percentage given);
- The rebalancing proposal was modified to continue to allow oilseeds to enter the EC free of duty;
- There would be a commitment providing access to the EC market for imports, equal to 3 percent of domestic consumption.

Although these concessions were touted as showing "considerable flexibility," they are really quite minimal. The most significant is the volume commitment on subsidized exports, but the lack of a percentage blunts the impact. Moreover, the EC wanted higher tariffs on corn gluten feeds, cessation of U.S. section 301 actions, and U.S. deficiency payments treated as export subsidies. The significant step in a general sense is the implied agreement to negotiate on all three elements of agricultural protection separately.

The day after these EC concessions were proposed, the "Hellstrom proposal" tested all countries' flexibility. Mats Hellstrom, the Swedish minister of agriculture chairing the agricultural discussions in Brussels, put forward a "nonpaper" that attempted to stake out some middle ground between the EC and U.S./Cairns proposals. It discussed:

- internal support: 30 percent cuts over five years from a 1990 base (or nearest year for which data are available);
- market access: tariffication and 30 percent cuts in tariffs over five years; minimum access commitments of 5 percent of domestic consumption where nontariff barriers exist;
- export subsidies: 30 percent cuts over five years based on budget outlays, per unit assistance, or total quantity, using 1988-90 base period.

The 30 percent reduction over five years amounts to 6 percent per year, a rate on an annual basis close to what the U.S. and Cairns Group had proposed and the same as the EC's proposal. But with respect to internal supports, cutting from 1990 levels means that credit would not be received by either the EC or the United States for the reductions in protection that occurred between 1986 and 1990. In both the EC and the United States these have been considerable. In spirit the Hellstrom proposal really is a significant move for the EC, and the EC, as well as Japan, refused to consider discussions based on it. That refusal triggered the walkout of Colombia and then other Latin American members of the Cairns Group that brought the Brussels proceedings to an end.

Events in 1991

The Trade Negotiating Committee met on January 15, and there were indications that Japan would accept negotiations in all three areas: internal support, market access, and export subsidies. (Korea has given similar indications.)

Potential EC policy changes include the MacSharry proposal, which seeks to reform the CAP and calls for significant cuts in and reorientation of support toward direct payments. For cereals, oilseeds, and protein crops, administered prices would be reduced by nearly 50 percent; per hectare direct payments would compensate for lower prices. Payments to small producers would be larger, and larger producers must cut acreage to receive payments (maximum of 35 percent cut in area). For milk there would be a 4.5 percent cut in global quota but larger cuts for big producers (up to 10 percent). Administered milk prices would be cut 10 percent, and there would be compensatory payments on the first 15 cows on each farm. For beef there would be a 15 percent cut in administered prices. There would be payments to encourage "environmentally friendly" farming methods. The income safety net payments to family farms would be reinforced and extended to help in transition resulting from CAP reform.

The MacSharry proposal is quite significant in terms of a reorientation of the CAP that would be consistent with a greater market orientation and Uruguay Round objectives. Issues raised include the amount of time it would take to implement CAP reform and how such reform would mesh with GATT commitments to reduce support and protection.

Future Directions

The EC seems to be moving in the right direction, but it is uncertain when it will be ready to return to the negotiating table with a clear mandate to negotiate in a framework of a Hellstrom-type proposal.

The United States must have congressional agreement by June 1, 1991, or lose the "fast-track" authority that requires Congress to accept or reject a GATT agreement as negotiated with no amendments. A request for fast-track extension, if made, must be submitted by March 1. The president must ask Congress for the extension and state why it is being requested. The extension will be automatically granted unless either the House or Senate passes an extension disapproval resolution. Any extension disapproval resolution introduced by a member must be referred to the Senate Finance and House Rules/Ways and Means committees. Neither body can consider an extension disapproval resolution that is not reported by these committees.

Assuming this hurdle is jumped, the negotiations can proceed seriously in 1991, their speed depending above all on the EC's approach. For the sake of the world agricultural trading system--and particularly the developing countries that rely on agricultural exports--let us hope a meaningful GATT agreement can be reached with all deliberate speed.

CAIRNS GROUP PERSPECTIVE ON THE AGRICULTURAL NEGOTIATIONS

Graeme Thomson

The Uruguay Round negotiations were scheduled to end in December at a Ministerial Meeting in Brussels. The meeting was unable to conclude the negotiations, however, principally because of a standoff on agriculture. The Brussels meeting clearly demonstrated that agriculture is the key to a successful outcome of the Uruguay Round. From this point on, it probably will be impossible to discuss trade liberalization and improvement of the trading system unless substantial improvements in the agriculture sector are also included.

The prominence of agricultural issues in the Round should not be underestimated. It contrasts sharply with the way agriculture has been neglected in previous multilateral trade negotiations during the 40 years since the GATT's establishment. That agriculture acquired the key importance that it did in Brussels must be related to the United States's strong support of agricultural trade liberalization and the efforts of the Cairns Group, as a coalition of both developed and developing country agricultural producers, in underscoring that the Round could not be concluded without a result on agriculture.

The seriousness of the Cairns Group position on multilateral trade reform is demonstrated by the willingness of the Group's developing country members to join in tabling an offer last October that required them to cut internal support by no less than half the target depth of cut that would apply to developed countries and to cut border protection by no less than 45 percent of the target applying to developed countries. Furthermore, given the target cuts specified in the Cairns Group offer, these developing countries were offering cuts to their own--already limited--support and protection levels greater than those offered by most of the industrial countries in the negotiations. This could indicate the constructive role that an increasing number of developing countries want to play in the international trading system.

While maintaining a firm position on agricultural reform in Brussels, both the Cairns Group and the United States were prepared to accept a compromise text submitted by the Swedish Agriculture Minister Mats Hellstrom. The Hellstrom text included a reform time frame and target depth of cut that were significantly less ambitious than those proposed by the Cairns Group and the United States. Nevertheless, the Cairns Group felt that the Hellstrom text provided an acceptable basis on which substantive reform commitments could be negotiated. It was therefore disappointing that the EC rejected the Hellstrom text. It was this rejection that effectively brought the Brussels meeting to an end. Consequently, it is difficult to imagine how substantive negotiations can be resumed until the EC clearly signals to other participants that it is prepared to adopt a more flexible negotiating position. In particular, the EC must unambiguously accept the need for specific commitments in internal support, market access, and export subsidies.

The Cairns Group does not think that the global proposal of the EC, i.e., reductions to an aggregate measure of support, would be capable of delivering the substantial progressive reductions in agricultural support and protection that were agreed to by Uruguay Round participants in April 1989. Instead, the Cairns Group position is that any commitments on an AMS must be

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accompanied by specific commitments on the most trade-distorting policies. Only explicit commitments on export subsidies will reduce the price-depressing and trade displacement effects of such industrial country subsidies on other countries that cannot afford to similarly subsidize their own exports. It is only through substantive reforms to border protection policies that these policies can be made more GATT-consistent and compatible with a liberalized trading system, especially through the tariffication of nontariff border measures into tariff equivalents that can then be reduced.

In the current world economic climate, a successful Uruguay Round could undoubtedly help governments in both developed and developing countries resist increasing protectionist pressures at home. From the more specific perspective of agriculture, the fundamental need for agricultural trade reform is once again being underscored by a renewed market downturn for many agricultural commodities. The fall in world prices in the wheat and dairy markets in particular has been exacerbated by increased use of export subsidies by the United States and the EC.

In Australia, the value of rural export is forecast to fall sharply by 14 percent in 1990-91, mainly as a result of falling export prices, and net farm cash incomes are forecast to fall 39 percent, to their lowest level since a severe drought affected much of the country in 1982-83. While Australia's rural producers are facing particular problems because of the difficulties in the wool market, the downturn across a range of agricultural markets at the same time has spurred, as in other countries similarly affected, increasing calls for government intervention to assist rural producers. Despite the depressed conditions in international markets for many agricultural commodities during much of the 1980s, Australia responded to these conditions by encouraging market adjustment and a removal of impediments to economic restructuring. Many developing countries similarly moved to encourage more open and competitive trading conditions in their economies.

In contrast to market-liberalizing moves in countries where agriculture is most important in terms of its contribution to employment, income, and export revenue, agricultural support and protection in the major industrial countries reached unprecedented levels during the 1980s. In recent years, often in response to the escalating budgetary costs of support programs, many industrial countries have initiated some limited reforms. In some cases these reforms have involved quantitative restrictions on production; in other cases support prices have been frozen or even reduced. Although these price reductions have usually been too small to have much impact on production, they have still been significant as tentative steps in calling a halt to the cycle of ever-increasing agricultural support.

One of the dangers of the current market downturn is that the industrial countries' response will be increased support at the expense of recent reform initiatives. This possibility could only increase in the absence of a satisfactory agreement on agriculture in the Uruguay Round. There are, of course, some encouraging signs that these reforms will be continued. The recently passed U.S. farm legislation has, at least for grains, instituted some movement away from the rigid production subsidy system toward more market-responsive agriculture. Reports have also come out of the EC that the Commission is about to come forward with proposals for CAP reform that will attempt to target support more effectively, including greater use of direct income support. Such initiatives, however, will only make a positive contribution to an improved trading environment if they are accompanied by (a) effective reform of the most trade-distorting policy instruments, whether export subsidies, variable levies, or quantitative import restrictions; and (b) substantial reductions in the production-inducing forms of support currently received by producers.

A particular challenge in finalizing an agriculture deal will be to ensure that it provides the basis for an equitable agreement with potential benefits for all participants. This is an issue of special importance to the

Cairns Group and its diverse membership. From a Cairns Group perspective, it will not be sufficient to have an agreement that deals with just a few of the major traded commodities--those most contentious among the leading industrial countries. Developing countries outside the Cairns Group have also been vocal on the importance of a comprehensive agreement that covers all agricultural products. Another key concern, if there is to be an equitable agreement on agriculture, is to ensure that this agreement is truly multilateral and liberalizing, in other words, an agreement that encourages open rather than managed trade and that is not subverted by special deals among a few countries over sensitive products or policies.

The Cairns Group has actively promoted the need for a multilateral formula approach to the negotiations, with all products and all trade-distorting policies subject to comparable reductions in support and protection, and to the strengthened GATT rules. When countries have legitimate concerns about reforming their agricultural policies, there are ways of meeting these concerns within a multilateral liberalizing approach to reform. For example, through exempting from reduction commitments minimally trade-distorting policies that could be used to meet so-called nontrade concerns or by providing a special transitional safeguard mechanism for products subject to tariffication of nontariff border measures.

This issue of a truly multilateral approach is of crucial importance to Cairns Group countries and to other developing countries and smaller trading nations for whom a framework of strong and effective multilateral rules and disciplines is the best guarantee of an equitable and fair trading environment.

THE URUGUAY ROUND AND THE NET FOOD-IMPORTING DEVELOPING COUNTRIES

Ransford Smith

The issue of how developing countries should be treated in the Uruguay Round agriculture negotiations has had two main foci: the general issue of what form special and differential treatment for developing countries should take and the related, though not identical, issue of what measures should be taken regarding net food-importing developing countries (NFIDCs). In the negotiations, neither of these two issues has yet received the thorough and focused consideration their proponents think they deserve. It is important to note, however, that at this point both issues remain firmly on the agenda of the agriculture negotiations. This paper will deal with the position taken by net food-importing developing countries in the negotiations.

The Montreal Mandate and Net Food-Importing Developing Countries

At the time of the Montreal Ministerial Mid-Term Meeting in December 1988, clear political support was given to addressing the concerns raised by NFIDCs. In Montreal the ministers agreed that "ways should be developed to take into account the possible negative effects of the reform process on net food-importing developing countries." This political mandate reflected and rewarded the persistent effort of a group of developing countries--in particular, Peru, Egypt, Morocco, and Jamaica--to have this issue addressed in the negotiations.

Overview of Concerns of NFIDCs

The concerns raised by NFIDCs flowed logically from the scope and sweep of the agriculture negotiations. The Punta del Este Ministerial Declaration, which launched the Round in 1986, called for improving the competitive environment through increased discipline in the use of all direct and indirect subsidies. The Montreal Mid-Term mandate two years later called for, among other things, "substantial progressive reductions in agricultural support and protection sustained over an agreed period of time." The vast bulk of support and protection in agriculture has been provided by the industrial countries, not by developing countries. During the 1980s, according to OECD Secretariat estimates, the total cost of agricultural support policies of OECD member countries escalated to over US\$250 billion per year, of which about \$120 billion was provided through government budgetary outlays. One clear consequence of this is that food imports for many developing countries have been available at prices lower than would have been the case in the absence of this high level of subsidization by OECD countries. This is particularly true regarding major food import items such as cereals and cereal preparations, oilseeds, oils and fats, dairy products, and meat and meat preparations. It must be emphasized that access to food imports at often artificially low prices has potential ramifications for the development of the agricultural sector in the importing developing countries. This point has been made in the negotiations.

Artificially low import prices contribute to the trend--still evident--of penalizing rather than assisting or creating a policy-neutral environment for the agricultural sector in developing countries. It nevertheless should be clear that in a climate of severe indebtedness and difficulties with balance of payments, few developing countries heavily dependent on food imports are likely--or should be expected--to agree to

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multilateral disciplines on agriculture that may worsen their external financial situation without at the same time insisting on off-setting measures to alleviate the anticipated adverse effects. This is the position that the NFIDCs have taken and have been defending vigorously.

It must be underscored that the NFIDCs have not opposed the general objective of a more liberal trading environment for agricultural products. They have emphasized that given the generally underdeveloped productive capacity of the developing world's agricultural sector, many of their countries are not likely to be able to take full advantage of the increased export opportunities resulting from liberalized trade in agricultural products--certainly not in the short to medium term. This is particularly true for NFIDCs. Although unlikely to incur early benefits from increased market access, these countries anticipate that they will, at the same time, face immediately the higher prices likely to result from the liberalization process.

This can hardly be a tangential issue in the negotiations. As table 1 indicates, the aggregate net food deficit of NFIDCs is approximately US\$28.272 billion (1984-86 average). Over 40 GATT Contracting Parties are numbered among NFIDCs, with Egypt the largest net food importer at US\$2.8 billion. Not all NFIDCs would--or should--be eligible for off-setting assistance because of their NFIDC status. In fact, some NFIDCs are among the higher-income developing countries--including oil exporters--with relatively strong external payment accounts, and they could be deemed capable of absorbing anticipated increases in food import prices. Thus, an important issue for negotiators will be criteria for access to off-setting assistance.

Two issues may be identified as having been central to the discussions on net food-importing developing countries. One is whether prices will rise as a result of agricultural liberalization and, if so, by how much. The other is what specific measures should be considered to assist NFIDCs.

To address the first question, NFIDCs have relied on the "consensus of the models" approach. The recent World Bank-OECD publication (see references) provides timely support. As the editors have observed, all the models point to increases in meat, dairy, and sugar prices, and all but one model forecast a rise in the prices of food grains.

Similar findings derive from a recent UNCTAD-UNDP-WIDER study (see references). On the assumption of either complete liberalization or a 20 percent reduction in producer support prices, international prices of wheat would rise by 20.4 or 7.5 percent, respectively; maize, by 15.1 or 4.8 percent; rice, by 42.6 or 18.3 percent; soya bean, by 3.6 or 0.0 percent; beef and veal, by 12.5 or 13 percent; and sugar, by 26.5 or 10.6 percent.

In a proposal to the negotiations in Geneva, and assuming complete liberalization in OECD countries, five NFIDCs (Egypt, Mexico, Peru, Morocco, and Jamaica) suggested that price increases for their major food imports could be in the region of 24 to 33 percent above 1984-86 outlays. Such estimates must be adjusted for an increasingly likely outcome of less than complete removal of support and protection. Additionally, the overall impact of the reform measures on a given NFIDC will depend not only on the scope of reductions in support and protection but also on the particular commodity composition of the importing country's food trade and the extent to which market access opportunities for its agricultural exports result from the reform process.

The second issue cited earlier as central to the discussions involves the specific off-setting measures that might be agreed upon and implemented. Net food-importing developing countries have proposed food aid (grant and concessional), financial assistance (bilateral and multilateral), and technical assistance to improve production and productivity in NFIDCs as well as to expand market access opportunities for their exports. It has been

**Table 1. Aggregate Food Trade of Developing Countries,
Average 1984-86
(millions of U.S. dollars)**

	Gross food imports CIF	Gross food exports FOB	Net
All developing countries	47,614	41,508	6,106
Net exporters	9,071	31,237	-22,166
Net importers	38,543	10,271	28,272
of which			
Egypt	3,057	207	2,850
Jamaica	168	106	62
Mexico	1,748	1,053	695
Morocco	569	343	226
Peru	416	80	336

Note: Food is defined by FAO to include all products that are considered edible and contain nutrients in their raw or processed forms. AGROSTAT Code 1982 excludes fish. Data are rounded. Negative sign (-) indicates net exports.

Source: FAO Agrostat files for 161 developing countries and territories.

emphasized that such measures--except, of course, expanded market access--would be temporary and limited to the duration of the accepted reform process. This emphasis ensures that off-setting action in the Uruguay Round would be clearly linked to the agricultural reform process and its consequences and not placed in the broader context of traditional assistance to developing countries. Moreover, it has been emphasized that off-setting action should entail "additionality" and not simply be included in normal levels of assistance. One obvious issue to be addressed is the modality or mechanism through which assistance to NFIDCs, if agreed upon, would be channeled. Egypt, Jamaica, Morocco, and Peru have proposed an Uruguay Round Window for Net Food-Importing Developing Countries. Essentially, they have proposed that during the Round a decision should be made to establish a time-bound window and an agreement reached on the general principles and guidelines for channeling off-setting resources of food aid, concessional sales, and financial assistance to NFIDCs.

Their proposal is that a base year could be agreed upon for the prices of basic food imports and that increases above the base year price during the course of the reform process could be subject to off-setting action through one of the modalities discussed above. Of course it must be negotiated whether all or some part of the increase in prices should be offset. Moreover, it is a difficult task to determine what part of the price increase is the result of the liberalization (or reform) process and what part is the result of current supply/demand factors. Some participants have expressed concern that the provision of off-setting assistance to NFIDCs would take the GATT beyond its usual realm of competence and into the arena of providing financial and other assistance. One response might be that the GATT does not appear at all reticent about expanding its sphere of competence, as reflected in the wide-ranging subject matter of the Uruguay Round. But perhaps more to the point, NFIDCs have emphasized that although decisions pertaining to off-setting measures could be multilaterally agreed upon in the Uruguay Round negotiations, the implementation of such measures need not be confined to the GATT but could take place, as appropriate, through existing multilateral agencies.

The Current State of Play

Although there has been clear political acknowledgment of the need to address the issues raised by the NFIDCs in the negotiations and in their outcome, there has not been a commensurate willingness to focus on the specific measures that might be implemented. Major participants such as the Cairns Group, the European Community, the United States, and the Nordic countries have all acknowledged the need to take into account the concerns of the NFIDCs. One specific modality--food aid--appears to have generated a significant measure of support, although there is caution that the provision of food aid should not be used to circumvent export subsidy disciplines that might be agreed upon in the Uruguay Round. This concern, of course, goes beyond the confines of off-setting action to assist NFIDCs and will be relevant generally to food aid and concessional sales in a post-Uruguay Round agricultural trading environment.

To some extent, the failure to treat more fully, at this stage, the specific ideas and proposals put forward by NFIDCs can be linked to the general lack of progress in the agriculture negotiations. Indeed, no negotiating text has yet been accepted as a basis for the negotiations and certain important parameter-defining issues remain unresolved. These include product coverage, policy coverage, the scope of reductions in support and protection, and the pace of reform--all issues, along with others, included in the list of principal issues for decision submitted by the chairman of the Trade Negotiations Committee (TNC) to ministers in Brussels in December. Until some of these issues are settled, it will be difficult to assess the precise impact of the reform process on NFIDCs. This has some merit, but in complex and difficult negotiations such as those taking place in the Uruguay Round there is a genuine danger that if issues important to a large number of participants are for whatever reason given second-tier status (whether in terms of their substantive treatment or their timing), it will be difficult to sustain the necessary political perception that a balanced outcome to the negotiations will be forthcoming. In the case under discussion, this difficulty is exacerbated because although some developing countries are low-cost agriculture producers and will clearly receive immediate benefits from liberalization (for example, the developing country members of the Cairns Group), there are a large number of developing countries whose assessment of the situation is less sanguine and more nuanced, given their low level of agricultural production and productivity.

As indicated earlier, this ambivalence is generally substantiated by the findings of those who have sought to provide "analytically based insights" into the possible effects of agricultural trade liberalization on developing countries. These effects relate not only to the direct impact of higher prices on food import bills but also to welfare effects for producers and consumers and importers and exporters of farm products. Even those models that suggest that developing countries will be better off (e.g., Anderson and Tyers, in Golding and Knudsen) do not necessarily entail for many of these countries benefits over the short term, but rather over time when dynamic effects such as inducement to invest in new technologies are considered.

The recent UNCTAD-UNDP-WIDER study, cited earlier, assesses welfare effects on an individual country basis. It finds that many developing countries that are net importers of basic foodstuffs--cereals, meat, sugar, edible oils--will experience net foreign exchange and welfare losses. Aggregating across countries shows that the African region as a whole will experience net foreign exchange and welfare losses under various liberalization scenarios. If the negotiating principle of "mutual advantage and increased benefits to all participants" is to be fulfilled, it is imperative that in this fundamental area of the Uruguay Round negotiations the concerns raised by NFIDCs be addressed in a timely and positive manner to ensure that there can be the fullest support for the outcome on agriculture.

In this context, it is fitting to quote from a recent report by the ACP Committee of Ambassadors in Brussels to the 51st session of the ACP Council of Ministers held in that city, November 28-30, 1990 (immediately preceding the inconclusive Ministerial Meeting of the Trade Negotiations Committee). The African, Caribbean and Pacific Group comprises 68 developing countries, many of them net food importers and GATT Contracting Parties. The report, in part, states that:

In the longer run a reduction or elimination of agricultural support and protection in the industrialized countries could have a dynamic impact on the development of agricultural production in the ACP states and could provide these countries with an opportunity to expand foreign exchange earnings from their agricultural exports. However, in the short to medium term, because of reduced production in developed countries and lags in expanding agricultural production in developing countries, world food prices can be expected to rise.

Higher prices would undoubtedly improve the profitability of the farming sector in some countries and reduce government expenditures on agricultural income support programmes in others. More remunerative prices in the long run could also contribute to making food production in food deficit ACP states more attractive. In the short run, however, high food prices would continue to increase pressure on the balance of payments of many food deficit countries, with serious consequences not only for their debt repayment capacity and their ability to maintain essential imports at adequate levels but also for the well-being of the poor whose food intake is already inadequate.

This reflects not only the concerns of ACP states but also those of other developing countries that are net food importers. These concerns should not be forgotten in the negotiations. The challenge for negotiators is to bring political goodwill and pragmatism, as well as a measure of innovative thinking, to negotiations to ensure a "balanced outcome" that will be broadly acceptable to all participants and will meet the expressed concerns of a large number of the smaller and poorer participants in the Round.

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SESSION IV:

**AGRICULTURE, NATURAL RESOURCES, AND
THE ENVIRONMENT IN THE 1990S**

WATER RESOURCES IN THE 1990S

Guy Le Moigne

Water is a major sector in Bank activities, affecting both economic development and environmental sustainability. For example, at the end of FY90, over US\$16 billion had been lent by the Bank for irrigation and drainage and \$11 billion for water supply and sanitation projects, representing 11 percent of total Bank lending (this percentage increases to over 13 percent if hydropower projects are included). Although Bank activities in the water sector have significant implications for the environment field, these dimensions have not yet been captured within a policy framework because interest throughout the years has generally been in designing projects providing water supplies sufficient to meet estimated demands of a particular sector, isolated from other sectors.

When there was little pressure on water resources, this single-project approach to water resource development was often adequate and logical. With increasing competition over limited water resources, however, the traditional, fragmented lending approach has become inappropriate. In one example, irrigation projects funded by the Bank in a middle-income country conflicted with other Bank-funded urban water supply projects, with both relying on the same sources of water.

In the past, nonetheless, the Bank has made several attempts to sponsor regional and river basin planning; some have been successful and have led to more efficient resource allocation and to the formulation of appropriate policies and strategies (for example, the Indus Basin studies). The Bank has also supported several major national water planning efforts, for example, in Bangladesh, Egypt, Mexico, and Pakistan, because of the need to formulate integrated water development plans in these countries.

The responsibility for such comprehensive water development efforts was usually determined by the Bank in an ad hoc manner. In the early 1970s, a special projects department was in charge of major water plans but was abolished during the 1972 reorganization. Shortly thereafter, a special unit was created to support the Mexico National Water Plan. It operated for about three years. In 1974, a water resources development division was formed in EMENA but operated only for one year.

Today the Bank's extensive experience in water development is widely dispersed among many Bank units dealing with water. Unfortunately, even the documents on Bank water planning and multisectoral efforts are difficult to locate because there is no single center in charge of water resources.

A number of Bank operational directives, operational manual statements, and operational policy notes address specific issues related to water resources development, including issues of international water rights, dam safety, resettlement of people, and more recently, environmental issues. The Bank, however, does not as yet have an explicit, comprehensive policy for addressing intersectoral water resources issues.

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Environmental Issues

Because irrigation activities in developing countries utilize about 80 percent of all consumptive use of water, it is appropriate to highlight the environmental challenges of the irrigation sector. Irrigation should be seen not only as essential to agricultural production but also as a component of environmental preservation. Although there is agreement on this broad statement, it is often difficult to calculate all the environmental costs and benefits of irrigation practices. Much work needs to be done on documenting the effects of irrigation on the environment and on formulating ways to reduce the damage caused by poor irrigation and drainage.

Irrigation projects modify the environment by reshaping the land surface and changing its hydrological regime. The construction of dams and irrigation channel networks affects soil moisture, changes the depth of groundwater, and alters water quality. At the same time, other human activities, such as dumping of waste, deforestation, and increasing use of chemicals and fertilizers, are clearly responsible for widespread damage to water quality and sustainability. Following agricultural and industrial growth in arid zones and the accompanying need for more irrigation, the problems of quality and quantity of water have become particularly pronounced. This has highlighted the need for prudent policies to preserve water resources and the environment.

Irrigation and drainage are often major components of water resources development projects, justified on the basis that they provide significant economic and other benefits, such as increased crop production and improved water management and flood control, while supplying needed power and sustaining water supplies to growing populations in both urban and rural communities. Irrigation has been instrumental in the economic development of many countries and has been a powerful means of generating income and creating employment. It allows countries to bring otherwise unusable land into production, helps increase yields by facilitating the introduction of more productive and higher-value crops, and promotes crop intensification by reducing the fallow period and by allowing farmers to grow several crops throughout the year. A recent study on the impact of irrigation in Thailand documented all of these benefits and added another important dimension: the benefits of irrigation to the environment were substantial because it drew large segments of the population away from the "slash-and-burn" culture that destroyed the forests and damaged the environment in the hills of Thailand. Irrigation allowed people to settle in the newly irrigated lands on the plains.

There is another view, however, of the effects of irrigation. A growing number of environmentalists and policymakers feel that many dams and irrigation systems have led to cultural uprooting of settled populations and environmental damage, thereby undermining development. Although all the costs and benefits of developing irrigation and drainage often cannot be easily calculated, imprudent and poorly designed irrigation development can have substantial environmental costs.

The following section will review the damages caused by excessive and inefficient use of water in relation to limited resources, waterlogging and salinity, health aspects, and sustenance of wild animals or plants.

Water Availability

Several rivers of the world, such as the Nile in Egypt and Sudan, the Euphrates in Syria and Iraq, the Jordan in Jordan and Israel, the Colorado in the United States, and the Amu Darya and Syr Darya in the Soviet Union, are now used so intensively for irrigation and municipal and industrial water supply that in very dry years there is inadequate water in these rivers. As municipalities and industry demand a greater share of available water, irrigated agriculture will have less water to produce more food for the

rapidly growing populations of developing countries. It is estimated that there will be critical water shortages in many parts of the world by the year 2010.

Waterlogging and Salinization

An inadequate supply of water is only one aspect of the problem. Poor management (that is, wasteful use of water) has also resulted in serious problems of waterlogging and salinization. Overwatering and lack of drainage often lead to a buildup of salt in the soil. Average-quality irrigation water may often require 5,000 to 10,000 cubic meters of water per hectare each year, with each hectare of land receiving 5 to 10 tons of salt. This salt concentration increases downstream, aggravating salinity problems in river deltas. The combination of a rising water table that produces waterlogging and an increasing concentration of salt thwarts the germination and growth of many crops.

Large irrigated areas in Egypt, India, Iraq, Mexico, Pakistan, the Soviet Union, and even the United States are all losing productivity as a result of the progressive deterioration of soils caused by salinization and rising water tables. Technical methods to deal with excess salts and water have been applied with mixed results in different parts of the world. For example, salt can be removed by using extra amounts of water for leaching. When this is done, however, the problem is often transferred elsewhere. If the resultant drainage water reenters the supply canal, the salt content of the irrigation water is increased for users further downstream.

Health Problems

Increasing reservoir and canal water supplies may also heighten the exposure of nearby populations to diseases associated with water development projects, such as malaria, schistosomiasis, and filariasis. Data available from major surface irrigation schemes indicate that these increased health risks cannot be neglected in project assessment. Schistosomiasis, for example, profoundly affects growth, physical working capacity, and productive output of infected populations. In Egypt, the loss of labor output among infected people is estimated to be more than 35 percent. In China, an average loss of 40 percent of adult capacity to work has been reported. Studies of sugar plantations in Tanzania and Sudan showed that infected workers produce 10 to 15 percent less than noninfected workers. Proper assessment of such projects can only be carried out, however, through adequate field research on the health risks of irrigation. We need to develop an approach in which health specialists can participate in this research to properly design services that prevent the occurrence of these diseases.

Sustenance Issues

Dams, reservoirs, and canals invariably affect the ecology of areas critical to the breeding or sustenance of wild animals or plants. Existing habitats of wild animals may be diminished or even eliminated. This controversy has elicited considerable and sometimes emotional protests from environmental groups. Water supplies may, however, be improved and new grazing areas created: these benefits should not be ignored.

A Comprehensive Approach

To deal with these issues of water management, one must look beyond simple project design and standard cost-benefit analysis. Recently, the Bank has taken steps to analyze these issues and plans to prepare guidelines for a comprehensive approach to water resources management that would address economic, institutional, technological, and environmental considerations.

One major economic issue relates to financial resources. As water allocation issues become more contentious, the water resources sector will place increasingly large demands on national budgets. Consequently, cost recovery questions will become even more critical. Water projects are typically heavily subsidized, and the cross-sectoral implications of implicit and explicit subsidies provided by governments are often not adequately considered, yet should be carefully reviewed. Cost recovery from beneficiaries has traditionally been difficult in most sectors. Practices vary widely among different systems, ranging from long-run marginal cost pricing for some hydropower projects, to direct cost pricing based on quantity consumed for a number of municipal and industrial water projects, to attempts to recover operating and maintenance costs in irrigation projects, to lack of cost recovery for flood control, navigation, and other in-stream water uses.

The effectiveness of these various attempts to recover costs are dependent on a number of factors, including overall government pricing and tax policy. Four factors are especially problematic. First, water is typically subsidized to achieve social goals such as poverty alleviation and food security. If water prices are increased to recover costs, other policy instruments may need to be used to meet these social objectives. Second, other market distortions introduced to further these social goals may promote inefficient water use. For example, crop subsidies may provide incentives for excessive use (from a strictly economic point of view) of both surface and groundwater supplies. Third, revenues from existing water charges are often returned to the general treasury and are thus not available for improvement of water services. Fourth, external costs such as environmental damages created by irrigation and drainage or sewage disposal are rarely incorporated into water prices. At the national level, one challenge is to define an appropriate balance between environment protection and income growth.

Both institutional and technical issues come into play. The institutional issues are affected by several factors. Government responses to increasing water demand and the emerging water allocation problems have typically been fragmented. Water resources planning and management are generally conducted with little interaction among agencies. In addition, staff training and incentives in many countries are inadequate for the tasks assigned to these agencies. Management and staff have little understanding of and no familiarity with the integrated approach to water management. Solutions to these problems will require organizational reform, strengthening of the agencies, training and educational programs, and changes in the legal and regulatory system.

The integrated approach to water resources development requires addressing technical issues, some of which are common to all sectors, some sector-specific. Among the issues common to all sectors is the comprehensive assessment of all water resources, including their quantity and quality (for example, the hydrological assessment in Sub-Saharan Africa). Another common issue is the monitoring of water quality to safeguard against public health and environmental hazards. More specific to the irrigation and drainage subsector is a new initiative, the International Program for Technical Research in Irrigation and Drainage (IPTRID).

Conclusion

The Bank should review cases of successful applications of policies designed within a framework of integrated water resources management. The lessons could point out effective practical solutions that could be used in Bank operations. The Bank needs to identify and further develop appropriate analytical tools for obtaining optimal allocations of water, both within and among sectors and countries. In addition, policy instruments, including pricing, need to be evaluated, and recommendations for policy reform made where appropriate. The proper assessment of the opportunity costs of transferring water across sectors is an important ingredient of efficient allocation decisions, and the Bank should review methodologies to facilitate

such assessment. The ranking of priorities among different objectives (not all of which have a straightforward market valuation) is another important issue related to the design of allocation mechanisms that requires study. Demand management and cost recovery and issues of institutional capacity need to be reviewed and formulated into guidelines for practical implementation.

As experience increases, the learning process is enhanced. New approaches that expand resource allocation and utilization efficiencies will result in departures from past practices. Once unquestioned assumptions about water resource development will frequently no longer apply. Irrigation impacts the entire water cycle, and thus Bank interventions must be viewed in terms of their system-wide consequences to optimize the total benefits of water resources.

TREE-BASED FARMING SYSTEMS

John Spears and Raymond Rowe

Much of the literature on the potential of trees to contribute to improved agricultural productivity is based on anecdotal observation rather than scientific measurement. To further the Bank's future work in this area, the first part of this paper summarizes scientific evidence on the impacts of trees on soil fertility and productivity. The second part of the paper offers illustrative examples of past or ongoing research that provides reasonably well-quantified data on the impact of trees on crop yields and productivity of various farming systems. The paper concludes with a brief summary of the current knowledge of economic evaluation of farming systems incorporating trees.¹

The Potential of Trees to Improve Soil Fertility and Productivity

It is reasonably established that incorporation of trees into farming systems can help to conserve soil and to maintain soil fertility and productivity in the tropics. Trees and other vegetation can improve the soil beneath them. Drawing on evidence from current land use systems involving trees, Nair (1984, 1987) offered some hypotheses on the beneficial effects of soils of tree-based farming systems. These have since been amplified by Sanchez (1987) and Young (1989).

Some of the beneficial effects of trees on soil include:

- maintenance or increase of organic matter. This has been proven and widely demonstrated, and is quantitatively known through studies of organic matter cycling under natural forest;
- nitrogen fixing. This has been proven, both indirectly through soil nitrogen balance studies and directly by observation of nodulation and tracer studies;
- nutrient uptake. This is probable, but has not been demonstrated. The hypothesis is that, in general, trees are more efficient than herbaceous plants in taking up nutrients released by the weathering of deeper soil horizons. Potassium, phosphorus, bases, and micronutrients are released by rock weathering, particularly in the B/C and C soil horizons that tree roots often penetrate;
- atmospheric input. Atmospheric deposition contributes significantly to nutrient cycling, more so in humid regions than in dry regions. It consists of nutrients dissolved in rainfall (wet deposition) and those contained in dust (dry deposition). Trees reduce wind speed considerably and thus provide favorable conditions for dry deposition;
- exudation of growth-promoting substances into the rhizosphere. This has been suggested but not demonstrated. Specialized biochemical studies would be required to demonstrate the presence and magnitude of any such effect and to separate it from other influences of roots on plant growth.

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Issues related to reduction of losses from the soil include:

- protection from erosion. The most serious effect of erosion is loss of soil organic matter and nutrients and the resulting reduction in crop yield. Forest cover reduces erosion to low levels, primarily through ground-surface litter cover and understory vegetation; the protection afforded by the tree canopy is relatively slight;
- nutrient retrieval. Tree root systems are commonly thought to intercept, absorb, and recycle nutrients in the soil that would otherwise be lost through leaching, thereby making a more closed nutrient cycle. The mycorrhizal systems associated with the tree roots are an agent in this process; they penetrate a large proportion of the soil, facilitating the uptake of nutrients that can move only short distances by diffusion. Evidence for this mechanism comes from the relatively closed nutrient cycles found under forest. The efficiency of mycorrhiza is demonstrated by the sometimes dramatic effects of mycorrhizal inoculation on plant growth (Atkinson et al. 1983; ILCA 1986).

Effects on physical properties of the soil include:

- maintenance or improvement of physical properties. The enhancement of such properties as soil structure, porosity, moisture retention, and erosion resistance under forest is well documented, as is the decline of these properties in forest clearance. Porosity is a key to many other physical properties: pores 5 to 50 μm in diameter determine available water-holding capacity, and those over 250 μm are necessary for root penetration. There is much evidence of the influence of physical properties of tropical soils on crop growth, independent of nutrient or other effects (Lal and Greenland 1979);
- modification of extremes of soil temperature. Studies of minimum tillage show that high soil temperatures adversely affect crop growth and that ground-surface litter cover greatly reduces the high ground-surface temperatures of bare soils in the tropics; these temperatures sometimes exceed 50°C (Harrison-Murray and Lal 1979). Leaf litter cover produced by trees is likely to have a similar effect.

Effects on chemical properties of the soil include:

- reduction of acidity. Trees tend to moderate the effects of leaching through the addition of bases to the soil surface. It is doubtful, however, whether tree litter plays a significant part in raising pH in acid soils, except through the release of bases built up during many years of tree growth, as in forest clearance or the chitemene system of shifting cultivation in northern Zambia;
- reduction of salinity or sodicity. Afforestation has been used successfully to reclaim saline and alkaline soils. For example, under Acacia nilotica and Eucalyptus tereticornis in the Karnal region in India, a reduction of topsoil pH from 10.5 to 9.5 over five years and of electrical conductivity from 4 to 2 dS/m has been reported, but with tree establishment assisted by additions of gypsum and manure (Gill and Abrol 1986; Grewal and Abrol 1986; Singh et al. 1988). In this type of reclamation, the improvement in the soil's chemical properties undoubtedly results partly from improved drainage (ditches), which leads to better leaching;

- effects of shading. Shade lowers ground-surface temperatures, which may reduce the rate of loss of soil organic matter by oxidation. Estimates of the humus decomposition constant are higher for agriculture than for woody fallows, although this may be primarily because of greater aeration of soil under cultivation.

Trees, both as individual plants and when grown in association with herbaceous plants, can have adverse effects on soils, including, for example:

- loss of organic matter and nutrients in tree harvest. A major concern in forestry is the depletion of soil resources by fast-growing trees and the effect of this on subsequent forest rotations. Trees accumulate large quantities of nutrients in their biomass, part of which is removed in harvest. The problem is greatest where there is whole-tree harvesting (for example, the gathering of fine branches and litter by local people after a timber harvest). From a soil management point of view, it is desirable to allow all branches and litter to decay in situ and even to return bark, but this often conflicts with the needs of local people, to whom such a practice appears unreasonable;
- nutrient competition between trees and crops. This problem is most likely to be serious when trees or shrubs have an established root system that dominates that of newly planted annual crops. The rooting systems of trees in farming systems should have deep penetration but limited lateral spread. Whereas lateral spread of the canopy can be controlled by pruning, root pruning is generally too expensive to be practicable;
- moisture competition between trees and crops. This is primarily a serious problem in the semiarid and dry savannah zones;
- production of substances that inhibit germination or growth. Some Eucalyptus species produce toxins that can inhibit the germination or growth of some annual herbs (Poore and Fries 1985). The production of allelopathic substances by tree roots could be problematic, but there is little research on this effect.

In sum, where the growth of crops or pastures located near or beneath trees is inhibited, research needs to focus on the degree to which this is caused by one or more of the above factors. Most of the beneficial and adverse effects of trees on soils mentioned above are either inferred from tree-based land use systems or are still only untested hypotheses. The degree to which they are significant in a given locale will depend upon site-specific factors. Moreover, many of the attributes of trees, compared with annual crops, can be assessed only over relatively long periods.

Nitrogen-Fixing Trees

Nitrogen-fixing trees are among the most promising components of farming systems. Because of their ability to fix atmospheric nitrogen and contribute to the soil via leaf litter and the turnover/decomposition of root debris and nodules, they have a dominant role to play in maintaining soil fertility.

Biological nitrogen fixation takes place through symbiotic means. Symbiotic fixation occurs through the association of plant roots with nitrogen-fixing microorganisms. Many legumes are associated with the bacteria *Rhizobium*; a few nonleguminous species are associated with the actinomycetes *Frankia*. Nonsymbiotic fixation is effected by free-living soil organisms and can be a significant factor in natural ecosystems--with their relatively modest requirements--but is of minor importance in agricultural systems, which

impose far greater demands on soils. Presumably, it varies according to the organic content and therefore the microbiological activity of the soil.

Nitrogen fixation by herbaceous legumes has long been exploited in agriculture by growing nitrogen-fixing species as a productive crop (for example, pulses and groundnuts), as a green manure crop (for example, Stylosanthes species and Centrosema pubescens), or as a cover crop in perennial plantations (for example, Pueraria phaseoloides). Nitrogen fixation rates for most herbaceous legumes are in the range of 40 to 200 kg N/ha/yr (Nutman 1976; LaRue and Patterson 1981; Gibson et al. 1982).

Nair (1988) examined the nitrogen-fixing trees in Asian farming systems and observed that several of them were already important components of these systems, providing a variety of services and benefits. Similar observations have been made in other parts of the tropics. In his review of the role of nitrogen-fixing trees in agroforestry, Dommergues (1987) concluded that the direct and indirect benefits of these trees vary greatly by species, climate, soil, and management practices.

Although a large number of nitrogen-fixing trees have been identified in various farming systems (Brewbaker 1987a; Nair 1988, 1989), few have received serious research attention. Those that have include Leucaena leucocephala (Brewbaker 1987b; Leucaena Research Reports); Gliricidia sepium (Withington et al. 1987); Sesbania species (Evans and Rotar 1987; ICRAF/NFTA 1989); Acacia (Faidherbia) albida (Felker 1978); and Prosopis species (Felker 1986).

Awareness of the importance of nitrogen-fixing trees has recently increased considerably, largely because of the efforts of the Nitrogen-Fixing Tree Association (NFTA). Based in Hawaii--but with a global network and a strong publications program--the NFTA has now progressed from listing nitrogen-fixing species in indigenous agroforestry systems and describing their characteristics to conducting research on nitrogen-fixation rates. Specific areas of concern are the effect of management and soil conditions on nitrogen-fixation rates and how much of the fixed nitrogen is made available to current seasons' crops.

Among the main sources of information on nitrogen-fixing species are the NFTA data base (Brewbaker 1987a) and the ICRAF multipurpose tree and shrub inventory (von Carlowitz 1986). Lists of the better-known or economically important species are provided in MacDicken and Brewbaker (1985) and von Carlowitz (1986). Nonleguminous nodulating species are listed in Bond (1976).

Measuring Nitrogen Fixation

There have been few direct measurements of nitrogen fixation by tropical trees, mainly because all three methods of measurement--acetylene reduction, nitrogen difference, and ¹⁵N labelling--are difficult to use (Roskoski 1986, Dommergues 1987).

In a plantation of Leucaena leucocephala in Tanzania, Hogberg and Kvarnstrom (1982) measured the instantaneous rates of acetylene reduction to ethylene and used approximate extrapolation and conversion factors to arrive at an N-fixation figure of 110 kg/ha/yr. Acetylene reduction measurements carried out by Roskoski (1981) in a Mexican coffee plantation indicated that whereas Inga jinicuil fixed over 40 kg N/ha/yr, a negligible amount was fixed by Inga vera. Because this technique is an instantaneous measurement of relative nitrogenase activity, it requires calibration of acetylene reduction rates against direct measures of nitrogen fixation and must take into account variations in activity with nodule biomass, soil nutrients, time of day, and season (Roskoski 1981, van Kessel and Roskoski 1981, Roskoski and van Kessel 1985).

In a recent study of L. leucocephala growing on alfisols at the International Institute of Tropical Agriculture (IITA) near Ibadan in Nigeria, Sanginga et al. (1989) showed that fixation was 76 to 133 kg/N/ha in six months when estimated by the difference method and 98 to 134 kg/N/ha in six months using the ¹⁵N dilution method. The study also showed that the application of nitrogen fertilizer reduced the amount of nitrogen fixed by the plants and that, when inoculated with Rhizobium, L. leucocephala derived about 5 percent of its nitrogen from applied fertilizer and about 55 percent from the soil.

Using difference and ¹⁵N dilution methods, Gauthier et al. (1985) estimated that fixation by Casuarina equisetifolia, grown in 1-m³ containers, was the equivalent of 40 to 60 kg/N/ha/yr. These methods were also used by Ndoye and Dreyfus (1988) in their study on Sesbania rostrata and S. sesban. The former fixed 45 to 51 percent of its nitrogen under flooded condition and 35 to 36 percent in well-drained soil; the respective figures for S. sesban were 11 to 13 percent and 18 percent.

Table 1 summarizes the reported rates of nitrogen fixation by trees and shrubs. Because of the shortcomings of nitrogen fixation measurement methods, these are very approximate. Most data refer to the tree in a pure stand, but the data for coffee with Inga species and alley cropping with Leucaena leucocephala refer to spatially mixed and zoned agroforestry systems, respectively. The range is large, from 20 to 200 kg/N/ha/yr; only L. leucocephala is capable of higher values under favorable climatic and soil conditions. There is a need for more data, but it is at least possible to identify trees and shrubs that, when grown in agroforestry systems, are capable of fixing 50 to 100 kg N/ha/yr.

Table 1. Nitrogen Fixation by Trees and Shrubs

Species	Nitrogen fixation (kg N/ha/yr)	Source
<u>Acacia (Faidherbia) albida</u>	20	Nair (1984)
<u>Acacia mearnsii</u>	200	Dommergues (1987)
<u>Allocasuarina littoralis</u>	220	Dommergues (1987)
<u>Casuarina equisetifolia</u>	60-110	Dommergues (1987)
Coffee and <u>Inga</u> . spp.	35	Roskoski and van Kessel (1985)
<u>Coriaria arborea</u>	190	Dommergues (1987)
<u>Erythrina poeppigiana</u>	60	Dommergues (1987)
<u>Gliricidia sepium</u>	13	Dommergues (1987)
<u>Inga jinicuil</u>	35-40	Dommergues (1987)
<u>Inga jinicuil</u>	50	Roskoski (1982)
<u>Inga jinicuil</u>	35	Roskoski and van Kessel (1985)
<u>Leucaena leucocephala</u>	100-500	Dommergues (1987)
<u>Leucaena leucocephala</u>	75-120	Mulongoy (1986)
<u>Leucaena leucocephala</u> (in hedgerow intercropping)	100-130 (6 mos.)	Sanginga et al. (1987)
<u>Prosopis glandulosa</u>	25-30	Rundel et al. (1982)
<u>Prosopis glandulosa</u>	40-50	Virginia (1986)
<u>Prosopis tamarugo</u>	200	Nair (1984)
Rain forest fallow	40-100	Greenland (1985)
Mature rain forest	16	Jordan et al. (1982)

Note: Nair 1984 and Dommergues 1987 are compilations from primary sources.
Source: Young 1989.

Nutrient Cycling

An advantage commonly attributed to incorporation of trees in farming systems is that they promote more efficient nutrient cycling than many other systems and thus have greater potential to improve soil fertility (Nair 1984). Results from a number of research efforts appear to support this view.

Sanchez (1987), in a review of all available information on this topic, reports encouraging results from experiments conducted to assess the nutrient cycling potential of agroforestry systems on alfisols and andepts of moderate to high fertility. Studies on the use of Erythrina poeppigiana as a shade tree in Coffea arabica plantations of Costa Rica have also shown good results (Glover and Beer 1986; Alpizar and Nair 1986; Russo and Budowski 1986; Imbach et al. 1989).

Juo and Lal (1977) compared the effects of a Leucaena leucocephala fallow versus a bush fallow on selected chemical properties in alfisols in western Nigeria. After three years, during which the L. leucocephala was cut annually and left as mulch, the cation exchange and levels of exchangeable calcium and potassium were significantly higher in the L. leucocephala fallow than in the bush fallow. Studies carried out by Agamuthu and Broughton (1985) showed that nutrient cycling in oil palm plantations where there were leguminous cover crops (Centrosema pubescens and Pueraria phaseoloides) was more efficient than in plantations where there was no cover crop. In addition to fixing about 150 kg/N/ha/yr, the loss of nitrate nitrogen through leaching was significantly lower in the former system.

Young (1989), drawing on studies on the nitrogen content of litter fall and prunings, provides data on various tree species in agroforestry systems in humid and moist subhumid climates and compares these with the data from natural vegetation communities. In hedgerow intercropping systems, some species are capable of supplying 100 to 300 kg/N/ha/yr, which is much higher than the amount removed during harvest or derived from nitrogen fixation (table 2).

A number of studies on soil changes under shifting cultivation have been carried out (Jordan et al. 1983; Toky and Ramakrishnan 1983; Andriessse and Koopmans 1984; Andriessse and Schelhaas 1985). However, there are no data as yet on nutrient cycling in farming systems based on shifting cultivation. The major inefficiency in shifting cultivation is that most of the nitrogen built up in the fallow period is in the vegetation, and much of this nitrogen is lost when the vegetation is burned.

Some tree and shrub species can selectively accumulate certain nutrients, even in soils that contain very small amounts of these nutrients. Palms, for example, are able to accumulate large amounts of potassium (Foelster et al. 1976), tree ferns accumulate nitrogen (Mueller-Dombois et al. 1984), Gmelina accumulates calcium (Sanchez et al. 1985), and Cecropia species growing on acid soils appear to accumulate calcium and phosphorous (Odum and Pigeon 1970). As Golley (1986) points out, however, the ability to accumulate nutrients varies according to particular sites and soils, and this factor must be taken into account when selecting nutrient-selecting species for incorporation into farming systems.

It is likely that the nutrient status of soils beneath trees is improved through canopy capture of precipitation inputs (Kellman 1979), but this needs further investigation.

It is important to distinguish between nitrogen fixation (an input into the plant-soil system) and nitrogen addition (through litter or prunings), which involves internal process in the soil. Much of the nitrogen in litter is taken up from the soil, originating either from stored reserves in the soil or from fertilizers. Therefore, two important questions arise:

- How much nitrogen is fixed by the tree component in agroforestry systems?
- How do trees improve the efficiency with which the nitrogen contained in the soil is supplied to the crop?

To answer these questions, studies on nitrogen balance must be carried out, taking into account the inputs and outputs of the plant-soil system as well as the internal processes. Data on atmospheric input, nonsymbiotic fixation, gaseous losses, and leaching are seldom obtained in nonspecialized trials and must be estimated by comparison with specialized studies conducted in similar environmental conditions.

Trees and Soil Conservation

The rates of soil erosion under agroforestry and other tree-based systems have been reviewed by Wiersum (1986) and, more recently, by Young (1989). The following summary is based on Young's review.

The effect of trees on factors of erosion involves:

- ground surface cover. The surface litter cover is far more important than the leaf canopy in controlling erosion. In plantation crop combinations, leaving prunings on the ground reduces erosion substantially. In a multistory tree garden in Tanzania, when crop residues were left as mulch, less erosion occurred than in forest. There are two reports of higher erosion occurring under trees on pastures than in pastures, but neither report suggests possible reasons for this;
- rainfall erosivity. Raindrops falling on high trees' canopies coalesce into larger drops, which then fall with a greater velocity than smaller raindrops. Higher rates of erosion caused by this factor have been recorded in forest plantations than in natural forests. Erosion rates recorded in a homegarden (Soemarwoto 1987) and a multistory tree garden were higher than those recorded in forest. It may be assumed that a low and dense canopy would reduce erosivity, but as yet there are no measurements to substantiate this. Under alley cropping, although the canopy is low, it is not directly above the cropped land;
- soil erodibility. Soil structure is of a higher grade and more stable, with lower detachability and higher infiltration capacity, under forest than under cultivation. Under shifting cultivation, organic matter declines, and erodibility increases during the cropping period. Under taungya systems, there is usually a decline in organic matter and infiltration capacity and increase in erosion during the cropping period. Alley cropping has the potential to maintain organic matter, or reduce the rate at which it decreases, whereas under monocropping there is almost invariably a decline in organic matter;
- runoff. It is well known that grass strips, bunds, terraces, and other soil-conservation structures reduce runoff and erosion, but it seems that no specific advantage is gained by the presence of trees on these structures. Barrier hedges seem to be effective in reducing runoff, as do the natural terraces formed by tree rows in alley cropping (Bannister and Nair 1990), but in both cases there are insufficient data to substantiate this.

Table 2. Nitrogen Content in Litter Fall and Prunings

Country/ climate	Land use	Nitrogen (kg/ha/yr)	Source
Nigeria/ subhumid	Hedgerow intercropping, 4 m rows, prunings: <u>Leucaena leucocephala</u>	200	Kand and Bahiru Duguma (1985)
	<u>Gliricidia sepium</u>	100	
Nigeria/ subhumid	Hedgerow intercropping, 2 m rows, prunings: <u>Leucaena leucocephala</u>	150-280	Bahiru Duguma et al. (1988)
	<u>Gliricidia sepium</u> (6 mos.)	160-200	
	<u>Sesbania grandiflora</u> (6 mos.)	50-100	
Venezuela/ subhumid	Coffee- <u>Erythrina</u> -Inga (unfertilized): trees only	86	Aranguren et al. (1982)
	trees and coffee	172	
	Cacao- <u>Erythrina</u> -Inga trees only	175	Aranguren et al. (1982)
	trees and cacao	321	
Costa Rica/ humid	Cacao- <u>Cordia alliodora</u> (fertilized)	115	Alpizar et al. (1986, 1988)
	Cacao- <u>Erythrina</u> <u>poepigiana</u> (fertilized)	175	
Various/ humid	Rain forest	60-220	Bartholomew (1977)
Various/ humid	<u>Leucaena leucocephala</u> , plantation: foliage	500-600	BOSTID (1984)
	litter fall	100	
18 sites/ humid	Forest	mean 134	Lundgren (1978)
Côte d'Ivoire/ humid	Rain forest	113, 170	Bernhard- Reversat (1977)
Brazil/ humid	Rain forest	61	Jordan et al. (1982)
California/ arid	<u>Prosopis glandulosa</u> (woodland)	45	Rundel et al. (1982)

Source: Young 1989.

Table 3. Rates of Soil Erosion in Tropical Ecosystems

Land use system	Erosion (t/ha/yr)		
	Minimum	Median	Maximum
Multistorey tree gardens	0.01	0.06	0.14
Natural rain forest	0.03	0.30	6.16
Shifting cultivation, fallow period	0.05	0.15	7.40
Forest plantation, undisturbed	0.02	0.58	6.20
Tree crops with cover crop or mulch	0.10	0.75	5.60
Shifting cultivation cropping period	0.40	2.78	70.05
Taungya, cultivation period	0.63	5.23	17.37
Tree crops, clean weeded	1.20	47.60	182.90
Forest plantations, litter removed or burned	5.92	53.40	104.80

Source: Wiersum 1986.

Observed erosion rates. Recorded erosion rates under tree-based systems are shown in table 3. Taking low rates of erosion as less than 2 t/ha/yr, moderate rates as 2 to 10 t/ha/yr, and high rates as over 10 t/ha/yr, these systems can be grouped as follows:

- Low** Natural rain forest; forest fallow in shifting cultivation; multistorey tree gardens; most forest plantations (undisturbed); tree plantation crops with cover crop and/or mulch
- Moderate or high** Cropping period in shifting cultivation; forest plantations, litter removed or burned; taungya, cultivated; tree crops, clean weeded

The data show that in the systems with high erosion potential, the range of values is large. This indicates that management practices, rather than particular types of land use, are more important in minimizing erosion potential.

Maintaining a surface cover of plant litter, which is possible in many farming systems incorporating trees, is the most effective way of reducing erosion. There are several types of agroforestry practices that, with good management, have the potential to reduce erosion to acceptable levels; these include multistorey tree gardens, planted tree fallows, alley cropping, plantation crop combinations, multipurpose woodlots, and reclamation forestry. In all these cases, however, what matters is not simply the presence of trees but the way in which the system is designed and managed. In designing a system for erosion control, the major aims should be to ensure a good surface cover of plant litter and to provide effective barriers against erosion by appropriate row alignment. Maintenance of soil organic matter, and therefore of the soil's physical properties and ability to resist erosion, is also important. Erosion control based on tree-canopy protection is unlikely to be effective, except when the canopy is low and dense.

Wind and soil moisture interaction. When wind is a major cause of soil erosion and moisture loss, a properly designed and maintained windbreak reduces the speed of the wind and thus its ability to carry and deposit soil and sand. Windbreaks can also improve the microclimate of an area by reducing water evaporation from the soil and plants, and in some cases they may increase plant productivity. An added advantage is that they can provide a wide range of useful products, such as poles, fuelwood, fruit, fodder, fiber, and mulch.

Windbreaks usually consist of narrow, multistorey strips of trees and shrubs planted at least three rows deep. They are placed on the upwind side of the land to be protected, at right angles to the prevailing wind.

They vary considerably in length and height. On the dry savannahs and steppes of Africa they are usually 100 m or more in length, with a maximum height of 10 m. Shelterbelts are a form of windbreak, but are planted many rows deep.

To be effective, a windbreak must be specifically designed to slow the wind. Very dense windbreaks may do more harm than good, as they will tend to create strong turbulence that will scour the soil on the windward side and damage crops on the leeward side. Gaps in the trees will channel the wind, increasing wind velocity on the leeward side and resulting in soil erosion and crop damage. Low growing hedgerows and live-fences can protect small units such as homegardens and nurseries from the wind, but are not specifically designed to act as windbreaks. Some examples of the impact of windbreaks on crop yields are discussed later in the paper.

Photosynthetic efficiency. The rate of photosynthesis depends upon the intensity of light, with the rate rapid at lower intensities and slow at higher intensities. However, plants vary considerably in their response to light intensities in terms of growth and competitive ability. A plant's physical architecture is one of several characteristics that determine its pattern of response to light intensities.

Understanding the way in which the components of a mixed plant community share light and solar radiation is a key factor in managing above-ground plant interactions in agroforestry. Some of the available light and solar radiation is intercepted by the top layers of leaves of the overstory species, while the rest is available to the understory species. The curve of net photosynthesis saturates at 20 percent of full capacity. Thus, a multistory plant configuration is possible where, for every unit of ground area, there is half a unit of leaf area at or near the top receiving full sunlight; half a unit of leaf area some distance down receiving 50 percent of full sunlight, but able to photosynthesize at full capacity; and yet another layer of leaves further down with leaf area equal to ground area, receiving only 25 percent of full sunlight, but still able to photosynthesize at full rate. There could therefore be twice as much leaf area as ground area, with all leaves operating at the peak photosynthetic rate.

There is considerable scientific data showing that, under practical field conditions, mixed plant communities have a better photosynthetic efficiency than monocultural stands. Although the leaf area index in a monocultural stand often exceeds 2, the leaves in the stands do not all photosynthesize at full capacity.

Root biomass, turnover, and nutrient storage. In mixed plant communities, the key factors in below-ground interactions are the structure and efficiency of the root systems of individual components, which determine the uptake of and competition for nutrients and moisture. Roots are a component of primary productivity, although they are seldom considered in conventional plant productivity calculations. Whereas the roots of annuals function on a seasonal basis, tree roots need to function all year-round. They also change their own environment by accumulating litter and redistributing nutrients. Trees have to contend with many changes in growth conditions, and thus they require efficient root systems with the ability to form a stable base, as well as the flexibility to accommodate changes quickly (Bowen 1985). In competitive environments, survival is the goal, and this will influence how much root is "necessary" for a tree.

The root biomass of trees is usually 20 to 30 percent of total plant biomass, although it may be as low as 15 percent in some rain forests or as high as 50 percent or more in semiarid and arid vegetation. This biomass consists of structural roots (medium to large diameter and relatively permanent), fine roots (less than 2 mm diameter), and mycorrhizae. Root abundance is expressed in terms of area (cm² of soil surface) or density (cm³ of soil volume). In general, rooting density and distribution of a particular plant depend on various site-related factors. Combining trees and

crops increases rooting densities and reduces interroot distances, which increases the likelihood of interplant competition (Young 1989).

One of the main difficulties in assessing the root biomass of trees by conventional core sampling or excavation methods is that the annual net primary production of roots is substantially more than the standing biomass found at any one time. This is mainly because fine roots are continuously being sloughed off and new ones regenerated (Sauerback and Johnen 1977; Sauerback et al. 1972), and thus the proportion of total photosynthate that passes into the root system is much higher than the standing biomass would suggest (Coleman 1976, Herman 1977, Fogel 1985). In some respects, then, the build-up and regeneration of the root system is similar to that of the above-ground biomass: the structural roots are comparable to the trunk and branches in having a steady increment and slow turnover, whereas the feeder roots, like the leaves, fruit, and flowers, are subject to shedding and regrowth (Young 1989). Similarly, above-ground litter fall and below-ground root turnover both serve to improve soil organic matter; this function of root turnover continues even when above-ground biomass is removed. Root turnover, and the effect of this process on soil organic matter, is a critical factor in the evaluation of agroforestry systems. The fine-root biomass data reported by Jonsson et al. (1988) from Morogoro, Tanzania (subhumid climate), for two-year-old *Eucalyptus tereticornis* (532 kg/ha), *Leucaena leucocephala* (616 and 744 kg/ha), and other species are one-off figures and thus unlikely to represent the total root biomass production of the plants.

Roots also store considerable quantities of nutrients. Jordan et al. (1983) reported that in a rain forest on a ferrasol, 10 percent of plant nitrogen occurred in the root system; in a forest on a nutrient-poor podzol, the figure was 40 percent. Koopmans and Andriessse (1982) and Andriessse et al. (1987) reported the following percentages and amounts of nutrients stored in root systems at two sites in successional forest fallows of shifting cultivation in Sri Lanka and Malaysia: nitrogen, 0.67 percent, 76 kg/ha; phosphorus, 0.04 percent, 3.5 kg/ha; and potassium, 0.57 percent, 53 kg/ha. Mycorrhizal associations (symbiotic associations between roots and soil fungi) are also important. Mycorrhizae absorb carbohydrates from the host plant, thus expanding the root system and increasing nutrient absorption. When trees are introduced into a system, mycorrhizal inoculation, like *Rhizobium* inoculation, will be extremely beneficial.

Effect of root interactions on soil fertility. One of the most important aspects of below-ground interactions in agroforestry is competition for the growth factors absorbed through roots--nutrients and water. Complementary interactions have been reported, but are far less significant than competitive interactions. To avoid or minimize the effects of this competition, the rooting patterns of trees and crops should differ in structure and depth. Nair (1979) has postulated that the concept of multistory plant combinations should incorporate both above-ground and below-ground configurations.

The deep-rooting characteristics of trees are often cited as desirable for agroforestry systems. This assumes that, because of their deep roots, trees are able to absorb nutrients from soil depths that crops roots cannot reach (Nair 1984). However, substantiating data are needed. Most of the fine, feeder roots of many common trees are found within the 20-cm-deep topsoil (Commerford et al. 1984). Radio-tracer techniques have been used extensively in studies of the root systems of horticultural tree crops, such as cacao (Ahenkorah 1975), apple (Atkinson 1974), coffee (Huxley et al. 1974), and guava (Purohit and Mukherjee 1974), but most of these studies have focused on the extent of the root systems, rather than on variations in uptake according to different soil depths. These studies have also shown that although subsoil nutrients can play an important role in orchard tree nutrition, nutrient uptake is not directly proportional to root weight.

Table 4. Leaf and Root Biomass in Nine Land Use Systems (kg/ha)

	<u>Agricultural systems</u>			<u>Forest systems</u>		<u>Agroforestry systems</u>			Planted fallow
	Young maize	Mature maize	Sweet potato	Gmelina plantation	Secondary forest	Coffea Erythrina	Cacao Cordia	Tree garden	
Leaf biomass	330	1000	1070	3120	3070	2720	2040	2450	2480
Root biomass (to 25 cm)	390	1150	410	1280	2170	2350	2720	3070	4220

Source: Ewel et al. 1982.

The contribution of roots to soil organic matter, and thus to soil fertility, has received little serious attention. The ability of the root system to improve soil organic matter even where all above-ground biomass is removed, as discussed earlier, is a crucial factor in low-input agricultural systems, albeit under low productivity levels. This emerges clearly from the data presented by Ewel et al. (1982), comparing root biomass with leaf biomass (not total above-ground biomass) for a range of land use systems in Costa Rica (see table 4). These data also show that total root biomass in agroforestry systems is substantially higher than in other land-use systems.

More information about the contribution of rooting systems to soil fertility is needed. When research reaches the point of designing plant ideotypes for agroforestry systems, the rooting characteristics of component species will be an important criterion.

Effect of species diversity on the ecology. Ewel (1986) argues that there are three potential ecological benefits of having several species in an ecosystem: full use of resources, pest protection, and compensatory growth.

An increase in species diversity and richness does not always lead to a more effective use of resources, but in any mixed plant communities, resource use is complementary rather than competitive (Connor 1983, Willey 1985). As indicated above, there are various mechanisms by which these communities use and share above- and below-ground resources, but in most agrosystems this pool of resources is limited. Therefore, the benefits of pest protection and compensatory growth are sometimes just as relevant to agroforestry systems as full use of resources.

Several factors have been cited to support the contention that mixed plant communities offer increased pest protection (for example, dense vegetation, comprising various plant forms, inhibits the movement of pests). However, plant diversity can also lead to an increase in pest damage of one plant species if a community acts as an alternate host to the pest of another plant species.

Compensatory growth refers to the process by which one species takes over and maintains the full use of resources if another species succumbs to, for example, disease, pest attack, or unfavorable weather conditions. Agriculturally, this is an important factor because it reduces the risk of total crop failure by spreading the risk among several components (Ewel 1986).

There are also particular benefits of a mixed species system that includes woody perennials. For example, the continuity of cover provided by these perennials may reduce soil erosion, lower the rate of evaporation for the soil, ameliorate the microclimate, and allow nutrients to circulate without interruption. Their extensive roots systems can also lead to fuller and more efficient use of soil resources than is the case in monocultural systems; however, it is not known whether the root systems of tree monocultures can exploit these resources as efficiently as stands of mixed tree species. The disadvantages of tree-based mixed species systems include

the fact that the yield of annual crops is usually much higher than that of perennials. Annuals have high net primary productivity, much of which is allocated to the reproductive or storage organs that are harvested for food or other purposes, whereas only a small proportion of the total biomass of perennial crops is harvested, except perhaps in the case of species grown specifically to provide fuelwood.

Agroforestry's advantage is that it is possible to combine the ecological benefits of perennial polycultures with the high yields that can be obtained from the monocultures of annuals.

The Potential of Trees to Improve Crop/Livestock Yields

The International Council for Research in Agroforestry (ICRAF) classifies the major agroforestry combinations as:

- agrosilvicultural (agricultural crops and trees);
- silvopastoral (pasture, animals and trees);
- agrosilvopastoral (agricultural crops, animals, and trees, with or without pasture);
- other (involving, e.g., horticulture, aquaculture, bees, wildlife).

To provide a comprehensive overview of the status of research for all of these different types of agroforestry farming systems is beyond the scope of this paper. The following sections provide an illustrative summary of some of the better known research results that clearly indicate the potential of trees to contribute to improved agricultural productivity.

The Interaction between Crops and Trees

Work by Shankarnarayan, Harsh, and Kathju (1987) at the Centre for Arid Zone Research in Rajasthan, India, studied the effect of intercropping Holoptelea integrifolia in crops of mung bean and cluster bean (guar) under different treatments: (a) crops grown between unlopped eight-year-old trees, (b) crops grown under lopped trees, and (c) crops without trees (i.e., control).

Under unlopped trees the grain yield was low, which indicated that shade had a negative effect on grain yield. Under lopped trees, mung bean yields were increased. It was argued that lopping not only had a beneficial impact on crop yield, but also provided fodder for cattle. These studies were repeated with Prosopis cineraria and Acacia albida at different spacements. The experiments also examined the impact of the rooting systems of the different tree species on crop yield to assess root-crop interaction for tree species with different rooting characteristics and their impact on moisture competition.

As the authors note, in traditional land use systems in Rajasthan, it is common practice frequently to harvest the foliage of species such as Prosopis cineraria and Ziziphus nummularia for both fodder as well as higher-grain yield. The authors claim that intercropping with trees is "now being adopted on a large scale in the arid parts of Rajasthan as well as other parts of India."

Similar work on the interaction between Acacia albida trees and sorghum/maize yields has been carried out in Ethiopia by Poschen (1986). Paired plots were selected in farmers' fields considering factors such as length of the growing periods, soil type, size density, and shape of tree. At each site a pair of plots consisting of one under the canopy and one in the

open away from the tree was demarcated. Twenty-seven sites spread over a distance of 80 kilometers were studied.

The yields of sorghum and maize were on average substantially higher under the tree canopy than outside. Averaged over all 27 plot pairs, the grain yields under the trees were 2.42 tons per hectare, compared with 1.55 in "without tree" plots.

The research suggested a density of about 20 trees per hectare, i.e., covering about one-third of the cultivated land, which seemed a reasonable target for an extension program. Economic evaluation considered the tradeoffs of lost crop area and the increased value of fuelwood and fodder. Similar research has been reported from Sudan by Miede (1989), who also identified Acacia albida-based agroforestry farming systems being practiced in Nigeria, Tanzania, Yemen, and Cameroon.

Alley Cropping (Hedgerow Intercropping)

Beginning in the mid-1970s, Kang and colleagues at IITA pioneered a concept of alley cropping (or "farming") designed as an alternative to shifting (slash and burn) agriculture. Food crops were grown in alleys formed by hedgerows of shrubs or trees, with careful management of the woody hedge to minimize competition for light. Hedges were coppiced primarily to fertilize crops.

Alley cropping has the potential to become an effective form of sustainable agriculture, in which the farm "grows its own fertilizer." Crop yields remained high after several years in the alleys, whereas control plantings failed in a few years. Although the primary advantage is to eliminate the bush-fallow period, added advantages of the hedges included off-season fodder or fuelwood, mulch, shade for weed management, and barriers against soil erosion. Superior shrubs, such as Gliricidia and Leucaena, proved to be N fixers.

Ongoing work on alley cropping is being undertaken in Rwanda using three leguminous shrubs (Leucaena, Calliandra, and Sesbania species). IITA and ILCA earlier reviewed the state of the art and identified research priorities for the future. The rationale for more intensive research in this area is the fact that this management system allows continuous low input and sustainable crop production on fragile soils in the humid and subhumid tropics.

Tree foliage provides high-quality supplementary feed for ruminant livestock. ILCA scientists established that supplemental high-nitrogen feeds greatly improved animal health, reproductivity, and weight gains in Africa. The feeds were based on Gliricidia or Leucaena clippings added alone or in mixture to African grass diets. Sustainable alley farms were created in which 0.2 ha provided half the daily requirement for about three sheep. Hedges were cut frequently to maximize digestibility and quality of foliage. On-farm trials showed farmer acceptability of the alley system, and station research showed that increased animal performance of about 30 percent was required to justify use of the legume foliage as browse, as opposed to mulch for the grass. Evaluation of many Gliricidia provenances revealed four outstanding yielders; field tests revealed superiority of seed planting to use of vegetative propagules through improved rooting (NFTA 1987).

Work on the potential of alley cropping systems is currently ongoing in several countries in different regions (in Africa, mainly Nigeria, Ethiopia, and Rwanda; in Southeast Asia, Indonesia, India, and Sri Lanka; and in Latin America, Colombia and Peru). Despite the positive results from alley cropping cited above, problem areas have been identified by ICRISAT (Oram 1989), which suggest that the system is more suited to tropical and subhumid rather than arid or semiarid agroecological zones. Socioeconomic research is

particularly needed to determine acceptability of the system to farmers and the economic tradeoffs between alley cropping and monocropping.

Silvopastoral Combinations

As part of its Tropical Pastures Program (TPP), CIAT has made a concerted effort to collect and evaluate tree and shrub legumes that are potential sources of forage. There has been extensive collection and evaluation of accessions of the genera Leucaena, Desmodium, Flemingia, Gliricidia, and others. The principal criterion for evaluation has been high dry matter production in the acid infertile soils that dominate the American lowland humid tropics. The TPP recognizes the potential value of tree and shrub legumes in pastures located in the humid tropics ecosystem not only as a source of forage but as a key component in establishing efficient nutrient capture and recycling that mimics natural ecosystem functioning (Oram 1989).

Pratchell's work in Botswana (reported by Le Houerou 1987), and similar research by Bille (1977) in Senegal; Enriquez (1983) in Costa Rica; and Shankarnarayan, Harsh, and Kathju (1987) in Rajasthan have studied the impact of dispersed trees on grass and protein yields in silvopastoral combinations covering a wide range of agroecological zones and soil types. The main emphasis has been on the potential of trees to improve pasture yields while simultaneously producing tree fodder and fuelwood.

In general these research results argued for retention of a light overstory of savannah-type trees to reduce wind velocity, increase soil moisture, improve soil microbiological activity capitalizing on the potential of some tree species for nitrogen fixation, and contribute to increased fodder yield (the experiments in Rajasthan on this point were inconclusive).

Aggressive, shrubby Leucaena varieties were planted as rows 8 to 20 m apart in native pastures in Queensland, Australia, and encouraged to grow as multistemmed trees. The system produced major improvements in animal gains and proved to be "productive and stable...compared with other sown pastures that demand higher management inputs for persistence and productivity" (Wildin 1989). Trees provided significant organic fertilizer to grass, important shade to animals, wind protection, and limited browse (mainly from seedlings) to animals. The author cites management options for increasing leguminous fodder, adapting to lower rainfall regimes, and achieving effective stocking rates.

Shelterbelts and Windbreaks

Early work by Magrath (1984) examined the positive and negative effects of shelterbelts on crop and livestock yields. Magrath's work was further developed by Anderson (1987), who reviewed the effects of shelterbelts on crop yields in 15 different countries.

Casuarina species (notably C. cunninghamiana, C. glauca, C. equisetifolia, and their hybrids) have been planted widely in Egypt and south China along farm boundaries and watercourses to act as windbreaks and to stabilize banks and prevent wind erosion of sand. In Egypt, these N-fixing trees grow rapidly to provide wind protection under severe stress of temperature and humidity. Coppicing may be practiced with low-growing crops. Research has identified superior germplasm for agroforestry systems (often species hybrid) and methods of planting, spacing, pruning, and managing that optimize performance.

In general, even allowing for the net loss of crop area as a result of the area taken up by the tree shelterbelt, appropriately designed tree shelterbelts have the potential in many situations to impact positively on crop yield (mainly as a result of reduced wind velocity and increased soil moisture retention, but also in some situations where leguminous species are used as a result of soil fertility improvement).

The majority of research on this topic has been carried out in developed countries. There is a major gap in research knowledge relating to shelterbelt-crop-livestock interactions in developing countries in different agroecological zones. Shelterbelt research priorities have been defined by ICRAF and others.

Boundary Planting with Trees and Use of Live Fences and Hedges

The planting of trees as boundary markers to serve as a hedge or as interspersed boundary trees for the production of fruit, fodder, or other products is widely practiced in many parts of the tropics. Few systematic studies could be identified on optimal tree farm management systems for improving the productivity of such trees and for ensuring that they do not negatively impact on adjacent crop yields.

Some of the better-known planting practices include lines of Borassus flabellifer (a palm species) around farm lands in the plains of Tamil Nadu in India, the planting of Grevillea robusta as a boundary marker (frequently pollarded for production of fuelwood) in Kenya, the planting of Euphorbia truncalli to demarcate farm boundaries and fields in Rwanda, Erythrina in Latin America, and the well-known Chinese "Four Around" system of boundary tree planting using Paulownia species.

Living fence posts serve farmers in many ways--demarcation, limit to access, support for barbed wire, fuelwood and fodder, and other products. CATIE and Udayana U. (NFTA 1987) seek to define silvicultural systems maximizing productivity of such linear plantings, focusing on fodder and postwood production. Evaluations include many optimal species, but focus on clonal variation in Gliricidia and Erythrina legumes. Pruning intervals were altered and production tables created for wood and fodder yields.

Indonesian research led to the establishment of 0.25 ha modules, now widely adopted, based on linear boundaries of an N-fixing tree, Gliricidia. The hedges surround a narrow fodder-grass strip, that in turn surrounds food-crop plantings (maize, cassava), and also include 1 Bali cattle, housed. Continuous cut-and-carry harvest of tree and grass foliage keeps animals at high gains, and manure and hedge clippings keep crops at good yield levels. Continuing research will identify superior clones for hedge and optimal frequencies and height of hedge trimming, on which the fertility and productivity of this sustainable agricultural system ultimately depend.

Apart from a few isolated examples such as the CATIE and Indonesian work, very little systematic, hands-on research has been done on the optimal choice of species, espacement, crop interaction, potential impact on farm income, reduced household risk, and protection of soil and water resources. Intuitively, it is reasonable to assume that such benefits do exist and could be quantified. As with many other agroforestry farming systems such boundary planting of trees has been widely adopted by farmers who clearly perceive their value.

Plantation Crop Combinations

Shade trees ("nurse trees") in plantations of coffee, tea, cacao, and other tree crops have been extensively used in the tropics. Significant early research showed that for coffee shade in Indonesia, quantifying N return from leguminous trees lopped in varying ways and frequencies.

There is fairly well-documented research on understory crops on plantations, such as that carried out in Sri Lanka by Liyanage et al. (1984) on the impact of undercropping of coconuts with different combinations of coffee/banana, banana/ginger/tumeric/pineapple, pineapple/papaya, banana mixed with coffee and cocoa, and coffee/black pepper. Such research indicated the potential for a significant increase in yield of coconuts when intercropped with different crops.

In a review of farming systems related to managing pastures and cattle under coconuts, Plucknett (1979) provides a comprehensive overview of future research needs with strong emphasis on improved understanding of crop-tree-livestock interactions.

Coffee production systems irregularly use "shade trees" that long-term CATIE research ("La Montana") showed to be important primarily as "nurse" trees, improving soil fertility in addition to protecting the coffee. Improved tree selection and management of Erythrinas led to increased coffee yields, and the introduction of premier timber species (e.g., laurel - Cordia) improved net economic gains of the system. Work by Beer (1989) showed that E. poeppigiana when pruned twice or three times a year can return the same amount of nutrients to the litter layer that are applied in coffee plantations via fertilizers even at the highest recommended rates for Costa Rica (270 kg/N/yr, 60 kg/P/ha, 150 kg/K/yr.) Critical to the effectiveness of nurse trees was the timing of pollarding. Superior Erythrina species and clones were identified for different ecosystems.

Farm Woodlots

The positive impact of cash crop tree farm woodlots on household income, farm risk, availability of fuelwood and building pole supplies, etc., has been well documented in, for example, the Philippines PICOP Program with Paraserinthes (Gregersen 1983), Eucalyptus farming in western Kenya (Deweese 1986), and poplar farming around Peshawar in Pakistan (Sheikh 1983). Chambers (1988) has reviewed the potential of cash crop tree farming to contribute to rural incomes and reduction of farming risks with special reference to smallholders. Conversely, Vandana Shiva (1987) and others have argued against Eucalyptus cash crop tree farming in India on the grounds that it deprives rural and landless people of access to common property lands from which they previously obtained essential supplies of fuelwood and fodder.

Past research in this area has been predominantly "traditional silvicultural research" (selection of fast-growing species; establishment methods; optimal spacings; and pruning, thinning, and coppicing regimes). Equity concerns call for more intensive socioeconomic research to clarify possible negative effects of cash crop tree farming.

Economic Evaluation

In general, knowledge in this area is very weak. The reasons for this relate first to the long-term nature of tree crop rotations and time required to develop meaningful analyses of the effect of trees on soil fertility and crop/livestock yields. Second, a limitation of most past economic analyses is that they are frequently based on research station results and/or certain assumptions that could differ significantly from field conditions. Third, there is evaluation of benefits. No matter how convincingly biological scientists argue in favor of agroforestry in terms of its long-term benefits (such as increased organic matter content), these attributes will remain "invisible" to economists until they can be translated into lower unit costs of production, visibly increased productivity, or some cost-saving differences in a social sense (Walker [personal communication]).

Finally, many of the past studies focused on long-term benefits and have not paid adequate attention to the interim, short-term benefits. For example, returns from wood products harvested later than five years after planting the trees are considered, whereas returns from the regular harvests of small branches for fuel and fodder carried out before the final harvest are ignored.

Any objective assessment of agroforestry's impact on the farmer must examine both the economic benefits and the costs. An analysis by Arnold (1987) of the positive and negative economic features of agroforestry is particularly relevant here (see table 5). The methods of carrying out such

Table 5. Main Benefits and Costs of Agroforestry

<u>Benefits and opportunities</u>	<u>Costs and constraints</u>
Maintains or increases site productivity through nutrient recycling and soil protection, at low capital and labor rates.	Reduces output of staple food crops where trees compete for use of arable land and/or depress crop yields through shade, root competition, or allelopathic interactions.
Increases the value of output from a given area of land through spatial or temporal intercropping of tree and other species.	Incompatibility of trees with agricultural practices such as free grazing, burning, common fields, etc., which make it difficult to protect trees.
Diversifies the range of outputs from a given area in order to (a) increase self-sufficiency, and/or (b) reduce the risk to income from adverse climatic, biological, or market impacts on particular.	Trees can impede cultivation of monocrops and introduction of mechanization, and thus (a) increase labor costs in situations where the latter is appropriate, and/or (b) inhibit advances in farming practices.
Spreads the needs for labor inputs more evenly throughout the year, reducing the effects of sharp peaks and troughs in activity, characteristic of tropical agriculture.	Where the planting season is very restricted, e.g., in arid and semiarid conditions, demands on available labor for crop establishment may prevent tree planting.
Provides productive applications for underutilized land, labor, or capital.	The relatively long production period of trees delays returns beyond what may be tenable for poor farmers and increases the risks to them associated with insecurity of tenure.
Creates capital stocks available to meet intermittent costs or unforeseen contingencies.	

Source: Arnold 1987.

analyses have been reviewed by a number of experts. Hoekstra (1985, 1990) provides a detailed examination of the issues or obstacles that economists encounter, as well as their options, in the appraisal of agroforestry projects. Magrath (1984) discusses the particular evaluation problems involved in agroforestry and provides a valuable survey of economic returns on agroforestry projects. Other important works in this field include those by Filius (1982), Arnold (1984), Betters (1988), and Prinsley (1990). Linear programming is now being adopted as a useful tool in economic evaluations of agroforestry. The multicomponent multiperiod budgeting (MULBUD) approach developed by ICRAF (Etherington and Mathews 1983) provides a possible microcomputer-based tool for economic evaluations.

Summary of Economic Analyses

Among the agroforestry systems on which economic studies have been conducted are:

Live fencing and intercropping

Reiche (1987, 1988) summarized posteconomic analyses of Gliricidia live-fences compared with dead-post fencing in Honduras and Costa Rica.

Alley cropping

Reviews of alley farming have been carried out by Kang et al. (1987), ILCA (1987), Walker (1987), Sumberg et al. (1987), Verinumbe et al. (1984), Ehui et al. (1990), and Ashraf (1990).

Intercropping and silvopastoral systems

Some ex ante and ex post analyses have been reported from India (Mathur et al. 1984; Gupta 1982; Shekhawat et al. 1988).

**Multistory cropping and
plantation crop combinations**

Some farm management and economic data issues such as labor utilization, cost of cultivation, and cost-benefit relations have been reported from coconut-based agroforestry systems in India (Nair 1979).

Homegardens

Arnold (1987) reviewed the results of economic studies on homegardens in India, Indonesia, and Nigeria.

Farm forestry/woodlot planning

Economic studies on "farm forestry woodlot" projects include an economic and financial analysis of smallholder tree plantations in the Philippines (Gregersen and Contreras 1979); work by Dewees on Eucalyptus woodlots in Kenya (Dewees 1986); case studies from eight countries on the economics of tree farming for fuelwood production (Energy/Development International 1986); an ex ante economic analysis of a farm forestry project in northern Nigeria (Anderson 1987); and an ex ante study comparing a Kenya fuel woodlot project with a conventional woodlot project (Hosier 1987).

The above listing is indicative rather than comprehensive. However, what does emerge from this brief review of the literature is that there is an obvious gap in knowledge and an urgent need to increase support for research in this field.

Notes

1. This paper is based on a more comprehensive review of this topic prepared for the World Bank's Agriculture and Rural Development Department by P.K.R. Nair (Nair 1990) and on a CGIAR/TAC paper that reviewed institutional options for incorporation of agroforestry into the CGIAR System (CGIAR/TAC 1990).

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SESSION V:

**THE MOVE OF PLANNED ECONOMIES TOWARD
MARKET-DRIVEN ECONOMIES: IMPLICATIONS FOR
AGRICULTURAL DEVELOPMENT**

AN AGRICULTURAL STRATEGY FOR POLAND

Claude Blanchi

The elaboration of an agricultural strategy for Poland was conducted using nontraditional Bank procedures. This paper discusses its origin and approach, as well as some lessons learned during the process.

Background

The concept of a task force to define a strategy for agriculture in Poland was articulated by the EMENA vice-president during his first visit to Poland in early 1990. The Polish authorities were worried that (a) no overall plan existed to help the transition of this important sector from the command economy; (b) supply response might not be forthcoming, creating food shortages in the country; and (c) the large increase in prices was adversely affecting farmers, who were used to subsidies, and unrest could thus develop both in the cities and in the countryside. They were also unable to direct the actions of the ministry, nor those of the donors. The authorities immediately agreed that defining a strategy was a priority.

The Bank had already done some excellent sector work, but it was not sufficiently comprehensive nor forward-looking to help articulate a lending strategy in terms of priority actions linked to the rest of the economy. A better understanding of the probable evolution of the sector during the adjustment process, and some clear ideas of the options available to the government, was needed.

It was thus agreed between the Bank and the Polish authorities that a joint task force would be created and would submit its analysis and recommendations by the end of July 1990 at the latest. The task force would be chaired by a senior Polish official, and experienced Polish technicians and academics would be seconded to it full time. The European Commission, which was given the responsibility by the Group of 24 to coordinate its assistance to Poland and Hungary, expressed the desire to join the exercise and did so through the financing of consultants.

Methodology

After a short mission in May to define the modus operandi with the government of Poland (GOP) and the EEC, the Bank assembled a team of 13 staff members plus 4 consultants. It was supplemented by seven consultants financed by the EEC. The Polish government selected a large number of Polish experts from the government and from academic and research circles to ensure that every foreign expert had one or more counterparts. Not all of these experts actually worked with the task force because it had been decided, in agreement with the EEC and the GOP, that the Bank and the EEC would finance only their incremental costs linked to travel and accommodation, but not fees, which would have to be covered by the GOP. Eventually, 34 Polish experts participated in the exercise. Many, but not all, spoke English. Translators were a necessity, and each subsectoral group had access to one interpreter on a permanent basis.

The task force was divided into several subsectoral groups:

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- economics;
- sociology, rural development, and agrarian structure;
- vegetal production, research, extension, mechanization, and inputs;
- animal production and dairy;
- trade;
- agroindustry;
- privatization of agriculture and agroindustry;
- cooperative sector and rural finance.

Forestry and fisheries were deliberately omitted so that the task force would not become too large and because these sectors required individualized treatment. (With hindsight, it was an error not to include forestry.)

During the first month (May 28 to June 27), the task force first visited relevant parts of Poland. For this field visit, the task force was divided in three groups, which occasionally divided into subgroups. The foreign experts were accompanied by their Polish counterparts and by interpreters, and the task force acquired a diverse and complete collective view of most of rural Poland and of the agroindustries. This field visit lasted 10 days. For the rest of the first period, the task force, reassembled into the subsectoral groups, worked to define the main elements of the strategy for their subsectors. Members of the task force visited many institutional and government officials, foreign donor representatives, and political personnel during this period. A challenge during that period was ensuring that task force members remain aware of the work done by their colleagues so that the necessary linkages would be preserved. This was achieved through daily meetings of (at least) all the subgroup leaders, who would present the status of their work and the evolution of their ideas. The leaders of economists' and sociologists' groups were asked to meet their technical colleagues on a daily basis, to ensure that their own economic and sociological views were recognized and understood.

At the end of the first month during a two-day workshop held in Warsaw on June 27 and 28, the task force presented its preliminary views to a select group of officials from the Bank, the EEC, the Polish government, and academic and political circles. With only the support of transparencies prepared in English and in Polish, each subsectoral group presented its preliminary findings and conclusions. Presentations were followed by a general discussion. The workshop benefited from simultaneous interpretation in Polish and English, to ensure that all Polish attendants could participate fully in the discussion. On June 29, Monty Yudelman helped the task force digest the remarks and interventions made during the workshop.

The rest of the period (through July 28) was used to write the main report. Each subsectoral group wrote one or several documents, which became annexes to the main report. Each document was prepared in Warsaw and was discussed and reviewed by other members of the task force and by the task force leader. Discussions outside of the task force, with ministers, members of Parliament, and other high officials, were held on a daily basis and helped ensure that the task force followed a reasonable course. During this time, things started to "heat up" in Poland, and the minister of agriculture was held prisoner in his ministry by irate farmers who wanted the reinstatement of support prices. The need for a strategy was definitely acute.

To ensure that the report could be read by as many people as possible in Poland, the task force proceeded with the translation of the subsectoral reports and of the main report as they became available. The difficulty of the task had, however, been underestimated, and the quality of the translations was not up to par.

Finally, on July 28 the report was delivered, without any prior clearance from Washington or Brussels, to the acting minister of agriculture.

The task force disassembled. A skeleton team went back to Washington to edit the Polish version of the report and to proceed with the printing of the substantial number of copies that had been requested (several hundred, both in English and in Polish). This was completed by the end of August.

The report had been circulated to senior decisionmakers in Poland, particularly Minister Balcerowicz. The ministry of agriculture used it to prepare its own submission to the council of ministers. Several of the report's conclusions are already being applied (particularly in research and extension). The report itself has now been widely circulated in Poland and among the donor community. The EMENA Region reviewed the document, as a yellow cover sector report, in September and officially submitted it, with minor qualifications, to the GOP. In October, the EEC convened a meeting of the Group of 24 in Brussels to review the report. Its conclusions were endorsed. The region is now preparing several agricultural projects based on the strategy.

Lessons Learned

The method of completing the work in Poland, by integrating a Polish team chosen by the government and without obtaining prior clearance from the Bank or the EEC, proved to be beneficial for Poland's circumstances. Poland needed some preliminary indications of where it should go and how. It could not wait for many months and was less interested in the Bank's final view than in a document that would be immediately usable and delivered in "real time." This is generally incompatible with normal procedures of short field missions followed by long periods of report writing in Washington. It was also essential to ensure that the mission members were willing to stay for an extended period of time (although only three stayed for the full two months) and prepared to complete their work in Poland, without the benefit of further deliberation. (It was, however, possible for some members to leave for a few days and then return.)

The complete backing of the authorities was essential. Both the foreign and the Polish experts knew that the GOP was anxiously awaiting the results. At the same time, the authorities never tried to influence the work of the task force. Its members were selected across a wide variety of origins and not exclusively from the ministry of agriculture or its related institutes. The task force felt free to explore its own ideas. There never was any attempt to satisfy a particular segment of the intended audience, rather only complete freedom to make the best possible analysis and recommendations.

It was also essential to have an integrated team, capable of looking at the macrolinkages, the sectoral linkages, and the sociological and political aspects of agriculture. Requiring the different subsectoral groups to understand what the others were doing was essential. Access to political personnel, including members of Parliament and representatives of the different political entities (including the Church), and understanding of sociological realities and long-term structures were essential to provide credibility to the recommendations.

A mid-term workshop with outside participants--high-ranking Bank and government officials--also proved to be useful. The team had to conceptualize its ideas before putting them to paper, and it had to present them orally with only the support of some visual devices. This accelerated the thinking process, increased the coherence of the ideas, and avoided countless drafts (generally used as a substitute for thinking). It was scary for most of us, but it ensured that we were then ready to write. The workshop audience also had to be prepared to be "guinea pigs" and to react to oral presentations rather than written documents.

The task force was entirely self-sufficient in terms of its computer equipment, both portable and desktop, photocopying and printing,

transportation, etc. All of this was financed by the EEC through a contract with a local firm. The ministry of agriculture, which served as host, provided only the office space and created the itinerary and the appointments for the field trips. We were also self-sufficient in terms of typists (one secretary from headquarters), interpreters, and translators. Most of the foreign experts could type themselves, and we all used the same software. This allowed us to work more efficiently than under normal circumstances. Given the short time frame, it would have been impossible to deliver the report on time if the support staff had worked on a nine-to-five basis, as would have been the case if we had depended on the ministry's staff.

Strategy Synthesis

The agricultural sector is important to Poland, but its economic potential has been impeded by the collectivization policies, first directly (production cooperatives, state farms), then indirectly (socialization of all upstream and downstream sectors).

Agriculture employs 28 percent of the active population, but its contribution to the GDP is only 12 percent. The revolt of farmers in the 1950s blocked the socialization of land and forced the government to keep 75 percent of the land under private ownership. This was achieved, however, with an attendant fragmented agrarian structure (average size of private holdings is 6 ha) and a complete dependence on the state for all services and marketing facilities. Almost all supply, credit, marketing, and processing functions are exercised by public enterprises or cooperatives.

The Agroindustrial Sector

Liberalization of the economic environment and increased efficiency of the agroindustrial sector are prerequisites to the development of agricultural production. The state and cooperative agroindustrial sector (which accounts for 20 percent of industrial production in Poland) still enjoys a de facto monopoly over marketing and processing of agricultural products. Because it is still managed by workers' councils, it continues to favor employment protection over efficient utilization of capital. Faced with a reduction of demand linked to the stabilization program, it tends to push down producer prices and push up its own prices (because of its monopoly), rather than increase its efficiency and decrease its cost to increase its sales. In addition, cross indebtedness of public enterprises contributes to inflationary pressures. The inefficiency of the agroindustrial sector hampers development of the agricultural sector. It is also a threat to the stabilization program because, in the absence of a functioning market system, farmers are liable to insist that the government reinstate price guarantee mechanisms.

Demonopolization and privatization of the agroindustrial sector (upstream and downstream) are prerequisites to a durable increase in its efficiency. Privatization of the agroindustrial sector should be a high priority. It should occur quickly and affect all enterprises. The first step is to reestablish public control over the enterprises and rescind the managerial powers of the workers' committees. State agencies responsible for ensuring ownership control over management in the interim period before privatization should be established. Considerations of equity suggest that privatization should not be undertaken to benefit the workers of the enterprises, but the public at large.

Demonopolization of the large enterprises into smaller profit centers should proceed rapidly to allow efficiency gains and to permit new entrants into the market. Enterprises should be freed of the social functions they have had to carry (housing, pension, social security, etc.). This supposes a public system of social security and a social safety net.

During the period preceding privatization, investment in public enterprises should be limited and subject to strict conditions of capital efficiency. State farms present a special case. There are 1,300 of them, constituting 4 million ha and employing 470,000 persons. They are organized as large units that cannot be dismantled and sold to private farmers without major temporary losses of capital efficiency. In addition, selling them to farmers would create large migratory movements and would depress the fledgling land market. Separating the ownership of the state farm land and buildings from their management has been suggested: land and buildings would become property of a state institute and would be leased to private enterprises or individual. The industrial enterprises of the state farms would be treated like public enterprises.

The cooperative unions, which have been liquidated, were the legal owners of many food processing enterprises, particularly in the dairy sector. Those enterprises should be returned to the primary cooperatives, which should become shareholders of these enterprises and manage, sell, or dissolve them, as appropriate.

Rural Development

An agricultural development policy must be supported by a rural development policy, and restructuring of the public sector must be accompanied by assistance to the development of small enterprises and self-employment activities in the rural areas, to help job creation and accelerate the privatization process.

Fifteen million people (40 percent of Poland's population) live in rural areas. Because of the scarcity of housing, population mobility is low. The increase in food and fuel prices, combined with the loss of employment in urban areas that will follow the industrial restructuring, will push more people into rural areas. The number of unemployed was about 1.2 million at the end of 1990, of which 400,000 resided in rural areas. Unemployment will first affect part-time farmers and then the numerous employees of the public and cooperative sectors.

The natural network of small enterprises, traders, retailers, and service enterprises, which normally exists in all rural areas, has been deliberately destroyed over the years. It should be possible to help reestablish those enterprises on a self-sustaining basis with relatively little investment.

Because of the small size of farms, multiple activities are the norm and will continue for some time. Already, a large part of the rural population performs nonagricultural activities. Promotion of small enterprises should be greatly aided by these characteristics. It will further require:

- a retraining policy for future self-employed individuals and for small entrepreneurs;
- access to credit for these categories of the population;
- a legal environment favorable to the development of small enterprises (legal and regulatory frameworks, market intelligence, access to technology and equipment, access to sites and services, etc.).

In the medium term it will also be necessary to improve rural infrastructure (principally water and, most urgently, electricity).

Economic Adjustment

Although the government must get out of directly productive activities and stop interfering with markets and prices, it still has an essential role to play. Until the transition period ends, domestic markets will be imperfect, and monopoly forces will still exist in the country. Government intervention will be necessary to provide some degree of stability and predictability of prices of commodities and credit. The government should refrain at all costs, however, from direct interventions in buying, selling, and storing commodities. It should also ensure that all budget transfers for price stabilization mechanisms are explicit and decided ex ante. Levels of price stabilization should not exceed the average CIF prices available to Poland.

The government is establishing a social safety net for those adversely affected by the economic adjustment. This function should be separate from the employment contract (particularly for housing) and should be extended to the rural and agricultural population. Support to vulnerable groups, in the form of non-market-distorting interventions (for example, food distribution), should be established and managed with the participation of local NGOs (particularly the Church).

Research and Extension

Agricultural research needs to be restructured and reoriented. Although its scientific level is high, it is almost exclusively concerned with yields and production levels and almost totally ignores the economic efficiency aspects of agricultural production. It is not adequately focusing on the private farmers. It does not need to be expanded in physical terms (indeed, substantial savings are possible), but it must be given new objectives.

Similarly, agricultural extension is inefficient, fragmented, and uncoordinated and is directly involved in large-scale production. It should be redirected toward efficiency of production, moving away from achievement of high production targets. Staff training should emphasize business orientation and efficiency of farm management, both for large industrial exploitations and for individual small farms. The extension service is large, and its reorientation may generate savings.

The cooperative sector and the rural financial system must be reformed, to reclaim their authenticity and efficiency. In the absence of an active private sector, the huge network of service cooperatives represents a potentially important asset for the farmers and a source of commercial competition for the private sector. Cooperatives need to be weaned from government control and from the de facto controlling power of their employees. New legislation is being designed to restore the exclusive control of the members over the cooperatives and to give them complete power over the disposition of the assets and profit of the cooperative. Cooperatives must be organized as private enterprises, without any monopoly powers or privileges over private firms, which require management and professional training.

The cooperative bank network is large (1,660 banks) and covers all villages. Its membership also is large (2.5 million people). It dates back more than a century and collects all the savings in the rural areas, which were siphoned out through their apex institution, the BFE. Although cooperative banks were under the complete control of the state, they have now reestablished their autonomy, and because they are close to their clients, they enjoy a relatively favorable reputation among their members. They are a valuable asset for savings mobilization and credit distribution in rural Poland. Creating a new system would take years, and it is doubtful that the newly created commercial banks will soon establish branches in the rural areas. The cooperative banks are therefore a major instrument for the development of rural areas. They need financial restructuring, to create

their own federal system, and technical assistance, to develop their managerial capacities.

The Agrarian Structure

Transformation of the agrarian structure will be slow. It supposes the creation of a land market and of all the institutions linked to it.

Twenty percent of farmers are over age 65, and many are part-time farmers who also hold salaried positions. As a result, about 500,000 farms are expected to disappear in the coming years. It is not advisable to try to accelerate this natural evolution, in view of the unemployment created by the economic restructuring. It is, however, necessary to create a land market and to remove the limits to land holding, in terms of size of the exploitation and the qualification of the landholder. In addition, a land lease legislation must be enacted. The huge stock of land owned by the state (through the Land Fund and also through the state farms) can be used to start an active land market, taking care not to artificially depress land values. Land consolidation needs to be undertaken, because fragmentation of farms is a major impediment to their productivity and efficiency.

All of these reforms are necessary to permit the development of the agricultural production potential in Poland.

Agricultural Products

Better utilization of fertilizers could allow cereal yields to increase by 15 to 20 percent, despite the constraints imposed by the climate and the relatively poor soil quality. Yields of sugar beets, potato, and rapeseed could increase by 10, 20, and 30 percent, respectively. Livestock will remain a major activity (principally pigs and dairy livestock).

Irrigation and drainage require improvement. The major step is to introduce concepts of economic efficiency to replace the purely "productivist" bent of the present system.

The industry needs to modify its products to better serve the needs of agriculture. This is particularly true for farm equipment, which should be of better quality and adapted to the needs of small farms. A reliable system of distribution of spare parts needs to be organized by the private and cooperative sectors. Fertilizer formulation needs to be reviewed, and there is a great need for livestock feed.

In addition, specific measures should be taken to facilitate marketing and processing of agricultural products:

- anti-trust laws, measures favoring the creation of new enterprises, and abolition of privileges and monopolies given to cooperatives and state enterprises (to increase competition);
- market information, creation of local markets, and assistance in creating professional organizations promoting quality and standards;
- training for managers and marketing specialists and training in accounting and auditing.

Summary: Environmental Issues

Finally, it appears that Polish agriculture is not, for the time being, a major contributor to rural environmental degradation. Farm chemical use is 20 percent of the per ha level of the EEC. Industry is by far the

greatest source of rural pollutants. Effective legislation on the use of restricted products, and an efficient enforcement system, needs to be developed. There does not seem to be any regulation or law regarding the disposal of old, deregistered, or unused pesticides. As farm chemical use expands in the coming years, it is critical that Poland establish a related code of conduct, consistent with international standards. Training on the safe use of chemicals and pesticides should be made available to farmers. Initial efforts in integrated pest management and biological controls should be encouraged and expanded.

THE MACROECONOMY AND AGRICULTURAL ADJUSTMENT IN POLAND

Odin Knudsen

Normally, when middle-income countries embark on major policy reforms of the macroeconomy--real devaluations, liberalization of prices, reductions in inflation, and trade liberalization--agriculture prospers. The real devaluation of the exchange rate raises the price of all tradable commodities in comparison with nontradables. Because agriculture produces largely tradable commodities, this devaluation raises relative agricultural prices while lowering the costs of distribution; agricultural producer incentives are thus boosted. Liberalization of prices eliminates the implicit taxation of farmers resulting from price controls that normally foster urban consumption. It also allows a relative price adjustment between various commodities permitting farmers to use resources more efficiently, thus raising their incomes. Reductions in the inflation rate reduce uncertainty in prices and should lower real interest rates, permitting stockholding and on-farm investments to be less costly and risky. Finally, trade liberalization allows domestic farm prices to be linked more closely to world prices, expands markets for agricultural commodities, and lowers input costs.

In many countries, these macroeconomic reforms have resulted in agricultural growth that has exceeded growth in other sectors. Although construction may suffer or import-substituting industries endure the adjustment costs of the transition to greater export orientation, agriculture responds quickly and normally booms. Governments initiating these reforms can point to their agricultural sector as illustrating the initial successes of their programs and argue that these successes will soon permeate the rest of their economy.

But this has not been the case in Poland. Although the reform program is still new--prices liberalized in August 1989 and macrostabilization in January 1990--there are few indications that success will be achieved in the next several years unless there are substantial additional reforms. Agricultural incentives have declined significantly despite relatively high international commodity prices, a massive devaluation, and price and trade liberalization. Despite the dramatic fall of inflation, resulting in a more stable real interest rate, farmers and merchants have failed to borrow. Stockholding has become entirely involuntary, a result of being unable to sell previously acquired stocks. Many agroindustries are suffering from high debt, exacerbated by large stocks of unsold commodities and low throughput. Consequently, Polish agriculture is in crisis.

The Macroeconomic Crisis and Stabilization

The government that took power in September 1989 faced an extremely difficult economic situation. Inflation was accelerating at triple-digit rates, fueled in part by a massive budget deficit equal to 8 percent of GDP. External debt amounted to 80 percent of GDP; debt servicing was five times export earnings. Growth had stagnated with per capita income now below 1978 levels, while government expenditures had grown by over 30 percent in real terms in the last decade (table 1).

Complicating the macroeconomic situation was the structure of the economy. Over 70 percent of the industrial sector was owned by the state. Exports were canalized by a few large enterprises that had survived on massive

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Table 1. Evolution of Economy, 1978-88

Macrovariables	Change per capita (%)	Household survey data	Change per capita (%)
Gross domestic product	-1.4	Real income of farmers	-3.1
Domestic absorption	-8.6	Real income of mixed HHs	-1.1
Consumption	0.7	Real income of workers	-24.7
Government expenditures	31.7	Real income of pensioners	-16.9
Gross fixed investment	-29.3	All households	-19.9
Percentage farmers' income/workers'			
1978	90.8		
1988	116.9		

export subsidies. But even more critical was the nature of decisionmaking in these firms. In 1981, the Polish parliament gave wide powers to the workers' councils, among them the power to hire and fire management. Management and labor had explicitly colluded, with the government--the nominal owners of capital--having lost control of costs and production yet retaining the ultimate obligation to fund the losses of these enterprises. Because of large subsidies to state enterprises and a substantial fall in revenues, the fiscal deficit reached 29 percent of budget expenditures in the first half of 1989.

In fall 1989 the government inherited an essentially bankrupt economy--unable to service its debt, in macroeconomic free-fall, and with a state sector outside its control. It had few options. Over 40 years of communist rule had accumulated in a rigid economic structure in macroeconomic ruin.

The new government decided to launch a critical, two-pronged attack on the unstable economy. In the first part of this strategy, the government attempted to gain control over the budget and prepare for the next phase by making some institutional and legal changes, mainly introducing unemployment compensation and bankruptcy procedures. On January 1, 1990, the second phase of the program was launched; its crux was a standard IMF-type stabilization package--fiscal and monetary restraints, a wage freeze, and a massive devaluation, followed by a fixed nominal exchange rate to serve as a nominal anchor. The stabilization package was designed to bring down inflation rapidly and to put pressure on inefficient state enterprises. With budgetary constraints in place, the government expected that the market would select inefficient state enterprises for bankruptcy and initiate the rationalization of the state sector. Unemployment was expected to rise, but this could be viewed as a sign of the success of the process: enterprises would be shedding excess labor and improving control over their wage bill. With improvement in efficiency and reduced costs, the cost-push part of inflation would be brought under control. Following macroeconomic stability, the real adjustments in the economy were expected to follow through a gradual process of enterprise restructuring.

Agriculture's role in this stabilization program would be threefold. First, it was expected to respond rapidly to the new incentives. Largely a private sector (about 75 to 80 percent of arable land is held by private farms), agriculture was expected to follow the incentives of higher relative prices and deliver food to urban areas at prices closer to world prices. Although higher food prices would mean falls in real wages, these drops would be moderated by the increased availability of both greater quantities and varieties of food. Furthermore, the hidden costs of food--for example, waiting in long lines--would be eliminated. Second, agriculture was expected to boost exports, easing pressure on the balance of payments. Although export subsidies were eliminated, it was expected that

about 80 percent of remaining exports would be competitive at world prices. In addition, the devaluation of the real exchange rate would compensate for the loss of export subsidies. Finally, agriculture would restrain rural-to-urban migration and perhaps absorb some of the unemployed from the industrial sector. With about 50 percent of the small farm population constituting part-time farmers employed in local state enterprises, a more prosperous agricultural sector was expected to absorb part of these displaced workers.

The Actual Outcome of the Stabilization

By most macroeconomic indicators, the stabilization program was a great success. Inflation crumbled under the stringent monetary and fiscal restraints, from a monthly rate of 79 percent in January to 24 percent in February to about 5 percent in May. Budgetary controls and increased revenues (from several reforms on enterprise taxation) produced a budgetary surplus, projected to be between 1 and 3 percent of GDP. Monthly interest rates followed the decline in inflation, undershooting inflation in January but becoming real and positive in February by 14 to 16 percent and falling to 1 to 4 percent in May. January's massive devaluation of about 100 percent (compared with the December rate) held: zlotys became readily convertible in Poland, and foreign exchange reserves expanded. Driving the foreign exchange accumulation was a contraction in imports and a rapid expansion of exports (imports contracted dramatically by 27 percent, and exports expanded by 14.5 percent from convertible currency areas in the first five months of 1990).

Table 2. Industrial Production, 1990

	January	February	March	April	May	January to June
Changes in percent with respect to the same month in 1989	-28.7	-31.5	-31.9	-31.9	-28.6	-30.1
Changes in percent over previous month	-10.1	-14.2	10.5	-8.6	3.5 ^a	

Note: Industrial production is output sold by socialized sector.

a. Correcting for different working days, the increase in May is zero.

But there were also signs of trouble (table 2). Real wages fell dramatically by 40 percent in the first quarter of 1990. Output declined by 30 percent in the socialized sector (29 percent below its level in May 1989).¹ Food expenditures rose from about 39 percent to 55 percent of total expenditures (compared with the first four months of 1989), reflecting the immediate pressure of food price rises on household real income. Unemployment, however, did not increase as expected. By the end of April, unemployment stood at only 2 percent of the labor force. Only a few firms had declared bankruptcy. Nevertheless, real debt was increasing rapidly, by 12 percent in March, 18 percent in April, and 3 percent in May (table 3). Also, there were various reports of lengthening delayed payments between firms. It appeared that the restructuring program had as yet not hit the state enterprises: labor was largely being retained, and enterprises were somehow holding on despite the magnitude of the macroeconomic adjustment.

Problems with the macroeconomic program were most evident in the agricultural sector, where the greatest successes were to have occurred. The very strengths of the agricultural sector that were to have led to its success--its largely private nature and its ability to respond quickly to incentives--rapidly brought forth the difficulties facing the macroeconomic adjustment program: the inability to achieve stability and a supply response

Table 3. Bank Credit to Public Enterprises, 1990
(billions of zlotys)

	December	January	February	March	April	May
Total nominal	30.6	31.79	39.45	46.09	58.78	63.5
% increase in month		3.89	24.10	16.83	27.53	8.03
Total real	30.60	17.80	17.83	19.89	23.47	24.14
% increase in month		-41.83	0.15	11.59	17.96	2.89
Change in real credit since 1/90 (%)			0.15	11.74	29.70	32.59

Source: Calculated from figures supplied by the National Bank of Poland.

through macroeconomic policies when the real structure of the economy remained distorted and economically concentrated.

The Effect of the Economic Program on Agriculture

Agriculture in Poland is a small sector, contributing to only about 12 percent of GDP; it would appear that agriculture would most likely be affected by the economic program but would not in turn influence the program's success. But this is not turning out to be the case. The effect of the economic program is straightforward. With the domestic market consuming about 87 percent of agricultural production, it is not difficult to foresee that the macroeconomic program and the resulting sharp recession could significantly affect the market for farm products and therefore the sector's economic well-being. But agriculture also has strong feedbacks to the general economy through employment (28 percent of the work force) and through its affect on the real wage rate (food expenditures range from 35 to over 50 percent of all expenditures, depending on income class). Furthermore, about 20 percent of industrial output comes from agroindustries, which in turn are dependent on domestic agriculture for 90 percent of their raw materials. The agricultural sector is more important to the economy than its economic size would indicate.

When the economic program began, the agricultural sector was highly protected and subsidized. From 1986 to 1989, food subsidies ranged from 3.4 to 4.8 percent of GDP (table 4). Although part of this subsidy was nominally for consumption, it was in part brought about by high producer prices. For example, producer prices for wheat during the late 1980s ranged from 10 to over 30 percent above equivalent border prices. For the state sector that produced most of the marketed wheat, the price support was even higher, averaging about 50 to 60 percent more than world prices. For milk, the producer support was nearly as generous, from 24 to 50 percent above world prices depending on the year. As with wheat, the support was concentrated in the state sector. This support through output prices was supplemented by input subsidies for fertilizers, pesticides, and animal feed at the rate of about 1 percent of GDP. Credit subsidies also were provided to the agricultural sector. In addition, export subsidies were given for certain commodities at a rate often half the value of the goods exported.

Aggregating these subsidies for the different crops results in the producer subsidy equivalent (PSE), or the total income supplement offered farmers and the state farm sector. In the state sector for wheat, this PSE constituted nearly 70 percent of the value of the wheat produced; for rye, about 50 to 70 percent; for sugar, about 50 percent; for rapeseed, about 40 to 50 percent; for pork, about 40 percent; and for milk, about 40 to 80 percent (table 5).² In other words, support for agriculture and processing on a per unit value basis was about at the level of many industrial economies.

Table 4. Agricultural Subsidies in Terms of GDP, 1986-90
(percent GDP)

	1986	1987	1988	1989	(est.) 1990
Food	3.5	3.4	4.8	3.8	0.2
Meat products	0.8	0.8	1.4	1.2	
Chicken	0.1	0.0	0.1	0.1	
Fish products	0.1	0.1	0.0	0.0	
Milk/milk products	1.6	1.4	2.1	1.6	
Flour	0.7	0.9	0.9	0.4	
Sugar	0.0	0.0	0.1	0.1	
Vegetable oil	0.2	0.2	0.2	0.2	
Baby food	0.0	0.0	0.0	0.0	
Milk bars	0.0	0.0	0.0	0.0	
Agroinputs	1.1	1.0	0.9	1.3	0.3
Fodder		0.4	0.4	0.3	0.0
Fertilizer		0.4	0.4	0.8	0.3
Tractors		0.0	0.0	0.0	0.0
Pesticides		0.1	0.0	0.2	0.0
Credit to agriculture	0.2	0.1	0.1	0.1	0.1
Total	4.8	4.5	5.8	5.2	0.6

Agriculture, especially the state sector, was sheltered and heavily subsidized. In 1988, average farmers' income exceeded that of urban workers by 17 percent (compare Hungary and Yugoslavia, where farmers' income is below that of urban workers by 4 and 20 percent, respectively).³

This subsidization ended abruptly with the macrostabilization program and the reduction of state expenditures. Food subsidies fell from about 4 percent of GDP in 1989 to less than a budgeted 0.2 percent for 1990. Agricultural input subsidies were to decline from 1.3 percent of GDP in 1989 to 0.3 percent in 1990. In addition, credit subsidies and export subsidies were nearly eliminated. In less than a year, a once highly supported agricultural sector (with support near Western European standards) had been released to survive in a deeply recessionary economy, still struggling to establish a market economy.⁴

The devaluation of the exchange rate should have partially compensated for this near elimination of direct subsidies. The real exchange rate (the nominal exchange rate corrected for inflation) devaluated compared with its 1989 level by nearly 50 percent. If this devaluation were transmitted to farmgate prices, then the net effect would have been a much more neutral adjustment in producer support.

But the price transmission did not occur, in part because of deliberate government policies and in part because of economic concentration in agroindustry. With inflation running rampant, the cooperative structure in disarray (the Cooperative Unions were dissolved), and a collapse in real producer prices, farmers withheld grains from the market in early and mid-1989 (for the first nine months of 1989, agricultural supplies to cities were reportedly down by 30 percent). The specter of a food shortage in urban areas was deeply disturbing to the government. Exports of essential foodstuffs were prohibited, and food aid urgently procured. With the blockage of exports, the arrival of food aid, and the sales of farmers to the milling industry

Table 5. Producer Subsidy Equivalents (PSEs)

	Wheat	Rye ^a	Barley ^a	Beets ^b	Seed ^c	Pork	Beef ^d	Milk
1986 Poland								
Private	46.2	37.8	64.9	32.8	50.1	28.1	15.7	57.1
State	68.2	62.3	87.3	56.7	75.5	36.6	4.0	77.9
European Community	63.0	66	66	76.0	57.0	5.0	50.0	73.0
1987 Poland								
Private	47.1	48.1	58.7	31.0	43.5		39.1	22.7
State	67.4	69.3	75.2	49.7	69.0		3.9	41.1
European Community	66.0	63.0	63.0	80.0	67.0	5.0	46.0	68.0
1988 Poland								
Private	34.2	28.1	32.0					
State								
European Community	30.0	34.0	34.0	71.0	59.0	6.0	56.0	60.0

a. Coarse grains used for EC's PSE data.

b. Refined Equivalent of Sugar used for EC's PSE data.

c. Soybeans used for EC's PSE data.

d. Beef and veal used for EC's PSE data.

Source: Polish data calculated by the Foreign Trade Research Institute in Warsaw. EC data published in Agricultural Policies, Markets and Trade, OECD, 1990.

increasing (because of the cooling down of inflation and rising interest rates), scarcity quickly turned to abundance. Exacerbating the situation was the decline in domestic food consumption, brought about by rising retail food prices and declines in real income. Stocks of grains and milk products accumulated, and farmgate prices plunged. Because of low demand for agricultural inputs, animal feeds and fertilizer sales also sharply declined.

Further aggravating the fall was the behavior of agroindustry. Although on an economy-wide basis it appears that the grain (the grain monopoly was broken up into 41 separate companies) and the milk industries are quite fragmented and competitive, at the local level they are highly concentrated. Collusive behavior, which had gone on for years (encouraged by past governments to meet the objectives of a state-coordinated sector), continued after prices were liberalized and most subsidies removed. The breakup of national monopolies created local monopolies, and a system of cost-plus pricing continued. Rather than lower prices to encourage sales, agroindustry restricted throughput, raised selling prices, and forced (through lower purchase prices) most of the industry's higher per unit operating costs back onto producers. Wheat fell to 60 percent of its border price; oilseeds, to 80 percent; pork, to 70 percent of its export price; and cattle for slaughter, to 59 percent of its FOB export price. The ratio of flour to wheat prices rose from about 3:1 on January 1, 1990, to 6:1 by the end of June 1990.

Heavy government support to agriculture had turned to indirect taxation through export controls, food aid, and oligopsony behavior. The government, recognizing the rapidly deepening farm crisis, released the ban on most agricultural exports except grains, where it remained bound by its food aid agreements to prevent reexport. For butter given as food aid, it canceled its request seeking the substitution of feed corn. But the crisis was now deeply imbedded in the sector. Meanwhile, the flush season for milk began, and the grain harvest began to loom on the late summer and fall horizon. High nominal and real interest rates made stockholding extremely expensive, adding to the indebtedness of agroindustry. Dairy cooperatives, the potato industry, feedmills, sugar processors, and part of the horticultural industry were

particularly hard hit. Farmers and some state farms, fleeing high interest rates and debt, quickly sold off durable goods and farm implements. Most dairy farmers received only extremely low and delayed (sometimes for months) payments for their milk. Agriculture, the only largely private sector in Poland, had been brought to its knees. But to rescue agriculture through subsidies meant opening the floodgate of subsidization elsewhere in the economy, because the austerity program now was beginning to take hold in other state sectors. With a collective consciousness, state managers began to contemplate the restitution of their state enterprises by the government. Macroeconomic stability was being threatened by the problems of a relatively minor sector (in terms of GDP)--agriculture.

The Structural Roots of the Farm Crisis

In the 1980s, the vision of agriculture held by the government was based upon income parity and self-sufficiency. Farmers should have been more or less receiving prices that guaranteed an income commensurate with urban wages. Imports and exports should have been restricted so that Poland would become self-sufficient regarding food. This policy produced a highly distorted sector that was unable to follow its natural economic progression, that is, one that would produce a diminishing share of GDP with a lower portion of the work force (agricultural employment remains extraordinarily high at about 30 percent of the labor force for an agricultural sector producing only about 12 percent of GDP).

Poland in the mid-1980s had an agricultural sector that was relatively large and employed more labor than countries of comparative real income per capita (especially if income comparisons are made on a purchasing power basis). This large sector did not occur by chance nor through absolute advantage: Poland's soils are only of moderate fertility, and its growing season is short. It occurred through a conscious government policy to promote income parity at nearly any cost through subsidies and guaranteed prices. In fact, on a per unit of value basis, subsidies, especially to the state sector, were equal to or higher than those of the EC and the United States. This highly supported agricultural sector now faces a new reality--that of market forces and world prices. The sector must adjust; the only question is how quickly it can.

There are two other major impediments to adjustment of the agricultural sector. The first is the state sector and its control of food processing and inputs. The second is the external barriers facing agricultural trade.

The State-Controlled Agroindustries as Barriers to Growth

In Poland, as in most countries, the efficiency and productivity of agroindustry are as critical to agricultural performance as good farm technology and management. In Poland, an estimated 75 percent of food is processed, and almost all agricultural inputs come from domestic industry. Between these "upstream" and "downstream" industries lies agriculture. Its farmers are dependent for their share of wholesale food prices on the efficient and competitive operation of food processing and distribution. Farmers also require high-quality and low-cost inputs such as seeds, fertilizer, and other chemicals from their input suppliers. Without the efficient operations of these industrial sectors, agriculture is helpless, and investments in improving farm productivity are nearly useless.⁵

Unfortunately, agroindustry in Poland is grossly inefficient and worse, generally unresponsive to market forces. In factor productivity growth, food processing ranked second to last in a sample of 17 industrial groups, with a decline in annual growth of 5.1 percent in productivity from the period 1978 to 1982 (table 6). With the overall resurgence in output growth between 1982 and 1985, food industry productivity growth became positive at 1.2 percent but still ranked second to last in growth. In

**Table 6. Total Factor Productivity Growth, 1978-85
(percent)**

1978-1982		1982-1985	
Best performances			
(1) Precision instrum.	2.7	(1) Precision instrum.	6.3
(2) Pottery and china	2.4	(2) Pottery and china	4.8
(3) Engineering	1.9	(3) Elec. engineering	4.4
(4) Metal products	0.7	(4) Engineering	3.6
(5) Wood	0.4	(5) Textiles	3.5
Worst performances			
(17) Bldg. materials	-5.3	(17) Paper	-0.5
(16) Food processing	-5.1	(16) Food processing	1.2
(15) Wearing apparel	-2.1	(15) Nonferrous metals	1.2
(14) Nonferrous metals	-1.6	(14) Ferrous metals	1.2
(13) Basic metals	-1.0	(13) Building materials	1.4

Source: Konovalov 1989.

international comparisons of competitiveness (as measured through Domestic Resource Coefficients [DRCs]), the food industry displayed the least international competitiveness of all of Poland's industries (table 7).⁶

In fact, the DRC measure for food processing was negative, indicating that the value of inputs exceeded the value of output when measured in world prices.⁷ Field visits to agroindustrial firms tended to confirm these numbers on lack of efficiency. Processing plants were generally a decade and half behind in technology.

This lack of efficiency is evident in other measures. In a 1988 sample of 500 of the largest state-owned industrial enterprises, about 10 percent were found to be loss-making, in the absence of subsidies and taxes (table 8). Of this 10 percent, about 80 percent were in the food processing industry. Of other industries that made losses, about 70 percent supplied agricultural inputs, animal feeds, and fertilizer. Although part of this loss-making is attributable to price controls, a major contributor is also the agroindustry's inefficiencies and antiquated technologies.

Beginning in August 1989, the government began the liberalization of prices with the objective of allowing the market to determine which firms were efficient. Unfortunately, the drive for efficiency through price liberalization confronted another barrier--the oligopoly structure of agroindustry (table 9). Agroindustry is highly concentrated, both on an aggregate level and on a regional level. For example, in a 1987 sample, two firms were found to have 47 percent of the market in food concentrates, 41 percent in oils and fats, 30 percent in vegetable and fruit products, and 30 percent in sugar products. In other industries, such as dairying, milling, and meat processing, the two-firm concentration ratios were lower (in the range of 2 to 20 percent of the market), but these low percentages concealed the regional oligopsony nature of the firms. With transport difficult to obtain and costs high, single buyers dominated many regional markets. Also, there is considerable possibility of collusive behavior among these state enterprises. One of the legacies of central planning is that a large number of enterprise directors and managers are accustomed to formal and informal economic coordination.

To complete this bleak picture, it is necessary to describe the response of enterprises to the economic reform program. Despite a dramatic fall in throughput and increasing indebtedness of enterprises, only one

Table 7. Domestic Resource Coefficients and Value Added, 1986

Group of industries	Value added domestic	Value added world prices	Short-run DRCs	Long-run DRCs
Metallurgical	15,411	5,785	1.15	4.00
Electro-engineering	89,208	70,802	0.55	1.32
Chemical	23,581	18,786	0.41	1.25
Mineral	8,981	9,177	0.49	1.05
Wood and paper	9,226	8,399	0.54	1.04
Light	40,601	30,373	0.61	1.01
Food	6,048	-3,803	-1.47	-3.40
Grand total	193,056	139,519	0.62	1.45

Source: Konovalov 1989.

Table 8. Loss-Making Enterprises, 1988

Sample of 500 largest state-owned industrial enterprises

Total number of loss-makers	56
of which:	
A. Food processing	43
of which:	
Meat products	23
Food-oil products	6
Poultry products	5
Grain products	5
Sugar products	3
B. Other industries	13
of which:	
Fodder production	6
Fertilizer production	3

Note: Coal mining was excluded.

agroindustrial enterprise has gone bankrupt, and few have significantly reduced their labor force. With workers' councils having the right to select and fire managers and the state still the nominal owner of (and thus eventually obligated to bail out) failing enterprises, no manager has the incentive to reduce his or her labor force or for that matter close the enterprise. In many ways, price liberalization has contributed to the worst case scenario--inefficient, oligopoly and oligopsony enterprises pricing largely as they wish to compensate for lower output and not reducing costs. It is impossible to conceive of a vibrant agricultural sector while it is hostage to such an uncompetitive and inefficient agroindustry.

A Major Barrier to Agricultural Recovery: External Trade Constraints

Poland's farmers have two markets: the internal market and the world market.⁸ The demand for food products in the internal market will largely be set by income growth; if Poland's income per capita recovers quickly from the severe recession and future growth is rapid, the domestic market will expand at a rate much less than overall income growth. Because of the severe fall in incomes in 1990 and slow growth forecast for 1991 and some later years, projections indicate that domestic consumption of food will not reach 1989 levels until the year 2000.⁹ That is, farmers can expect that the domestic market's ability to absorb domestic farm produce will be limited;

Table 9. Economic Concentration Ratios of State Firms, 1987

	One-firm	Two-firm	Four-firm
Outputs			
Food concentrates	0.31	0.47	n.a.
Oils and fats	0.28	0.41	0.66
Potato products	0.27	n.a.	n.a.
Fruit and vegetable products	0.23	0.31	0.40
Flour milling products & pasta	0.09	0.14	0.24
Eggs and poultry	0.08	0.15	0.28
Milk and milk products	0.02	n.a.	n.a.
Sugar and sugar products	0.19	0.30	0.51
Inputs			
Tractors	0.90	0.96	n.a.
Fertilizer	0.22	0.43	0.73
Farm machinery	0.15	0.23	0.35
Animal feed	0.14	0.26	0.51

Source: Rocznik Statystyczny Przemyslu 1988.

nevertheless, the domestic consumers will have to remain the primary market for most food output.

The export market for certain products--meat and fruits and vegetables--will remain strong but will be limited by external trade restrictions. Poland's agricultural exporters face variable import levies, quotas, minimum prices, and "voluntary" export restraints for most agricultural exports to hard currency areas. These restraints to trade are particularly pronounced in the EC, which currently constitutes about 50 percent of Poland's agricultural export market (table 10). Agricultural exports to nonconvertible currency areas remain small--about 1 or 2 percent of total exports to these areas (table 11). Some expansion in these markets can be expected as the Soviet Union adjusts its agricultural policies, but at the least, the prospects are highly uncertain (this trade is expected to become convertible in January 1991).

Polish exporters also face the constraint of a highly concentrated export trade--five state enterprises dominate agricultural exports (table 12). These enterprises are resistant to new competition yet continue to maintain old channels for trade and methods of doing business. Without additional private sector competition in exporting, agricultural exports will remain confined, and diversification, in terms of both products and markets, will be hindered.

Table 10. Agricultural and Food Exports, Mainly to Hard Currency Countries, Increasing Share to EC Countries (total = 100%)

Convertible zone	67.4	77.2	81.9
Of which:			
EC countries	31.1	34.6	50.1
United States	12.1	12.8	10.5
Soviet Union	13.3		

Source: Polish-European Community-World Bank Task Force 1990.

**Table 11. The Share of Agrofood Export in Total Export
(total export = 100%)**

	1989		Jan-May 1990	
	Food	Agr. Prod.	Food	Agr. Prod.
I Nonconvertible zone	1.6	2.0	1.5	1.3
II Convertible zone	13.8	5.8	12.5	7.1

Source: Polish-European Community-World Bank Task Force 1990.

**Table 12. Oligopolistic Position of Foreign Trade Organizations,
Centralas, in Agrofood Import and Export
(share in percentages)**

	Animex	Rolimpex	Rybex	Agros	Polcop	All together
Export	31.6	21.1	10.0	9.5	4.9	77.1
Import	9.1	39.9	5.0	20.8	3.0	77.8

Source: Polish-European Community-World Bank Task Force 1990.

On the positive side, the real exchange rate has depreciated significantly, providing a strong incentive to export. However, inflation persists, and each day it appreciates the real exchange rate (as long as the nominal exchange rate remains fixed), reducing export competitiveness. The race is then between devaluations and an inflation rate that erodes export competitiveness; eventually, though, each feeds on the other. At a 5 percent rate of monthly inflation, incentives offered by a 50 percent undervalued exchange rate will evaporate in less than nine months without further nominal devaluations.

Conclusions

Almost overnight, agriculture in Poland has gone from a highly protected and subsidized sector to a somewhat indirectly taxed sector. In addition to this abrupt transition, agriculture faces a difficult macroeconomic situation of falling domestic food demand and high interest rates. Overshadowing even these difficult problems is the legacy of inefficient agroindustries and lethargic export enterprises. Finally, many export markets remain constricted by protectionist policies of trading partners. Under such circumstances, it is difficult to be optimistic about the prospects of Poland's agricultural sector.

A potential additional danger is an overreaction by the government that could exacerbate the economic situation by imposing price controls and guarantees, creating state enterprises to intervene in the market, providing large subsidies, and enacting excessive import and export controls. Taken at the height of a farm crisis, these interventions could become barriers to achieving a more efficient economy in the future.

This danger does not mean that the government should be inactive in addressing the current farm crisis. Some actions have already been taken: creation of an agency to trade in futures contracts based on certificates of storage; incentives to store butter (see Polish-European Community-World Bank Task Force 1990); longer-term loans at fixed nominal interest rates (but at real interest rates); and demand stimulation through food stamps and direct feeding programs for school children, pensioners, and other vulnerable groups initially harmed by the economic reforms. On the trade side, the government should continue to maintain an attractive exchange rate for exports and attempt to negotiate market access for its products.

Finally and most important, the sector must privatize. With output markets, external trade, and input supplies dominated by state enterprise responding to noncommercial incentives, it is difficult to imagine a vibrant agricultural sector. Because the problems of agriculture are intensifying--the farm crisis is already upon the sector--privatizing agroindustry must occur soon and rapidly.

Notes

1. These numbers may overstate the severity of the fall because production in the private sector is not recorded.

2. Some caution should be exercised in interpreting PSE numbers for Poland because the exchange rate is a confusing factor. However, if estimates of the real exchange rate from the World Bank and IMF are used to correct the PSE numbers, then the level of subsidization actually increases for 1987 and 1988 because these estimates point to an undervalued exchange rate (compared with 1980) for those years. From 1982 to 1985 the exchange rate was overvalued (compared with 1980); subsidies helped to compensate for this overvaluation in those years.

3. In the first quarter of 1990, however, farmers' income was 86 percent of workers' income.

4. This is most evident in the dairy sector, where subsidies reached nearly US\$1 billion in 1988, fell to US\$70 million in 1989, and nearly disappeared in 1990. This sector contributes 19 percent of agricultural GDP and provides an important source of cash to over 1 million small farmers.

5. The reverse is also true: agroindustry depends on the efficiency of agriculture. This also has broader economy-wide implications because the food industry share of all industrial output is about 20 percent; of (convertible) exports, 13 percent; and of employment, roughly 10 percent.

6. These results are based on results from Konovalov 1989.

7. There was considerable variability of results, with the dairy and meat industries being the least competitive and soft drinks and millery products being more competitive.

8. See Polish-European Community-World Bank Task Force 1990 for a more elaborate analysis of Poland's agricultural trade and its prospects.

9. See Polish-European Community-World Bank Task Force 1990 for details on the projections.

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THE AGRICULTURAL TRANSITION IN THE U.S.S.R.

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Agriculture is a key economic sector in the U.S.S.R., accounting for about 20 percent of GNP and 19 percent of employment. Over 100 million people, or about one-third of the country's population, depend directly or indirectly on the sector for their livelihood. The area cultivated--from the fertile "black-soils" in the center of the country to the poorer quality soils to the north and the irrigated lands in the south--covers about 230 million hectares, giving the U.S.S.R. the most extensive land wealth of any country in the world. Most of the land is planted in grains and fodder crops, while overall, half the value of production comes from livestock products. Ninety-seven percent of the land is farmed in the public sector, about equally in large state or collective farms. Despite this favorable resource endowment, Soviet food imports range between US\$15 and \$20 billion per year, of which about one-half are grains and sugar. The Soviets absorb approximately one-quarter of world exports of grain and sugar.

Soviet agricultural performance continues to worsen, while substantive reforms in pricing, property relations, farm organization, and marketing are delayed. Recent deterioration in agricultural marketing has compounded the chronic problems of the sector: inefficiencies in production and processing, deficiencies in distribution and waste at all stages between producers and consumers, and low returns to investment. The deterioration in marketing results, in part, from fragmentation of the political and economic linkages of the administrative command system, and in part from the decline in the willingness of farms and processors to accept fixed government prices and rubles for transactions. The result has been shortages in cities and the growth of autarky and barter. (In winter 1990 availability of food in Moscow, Leningrad, and the industrial cities of the Urals was lower than average, and supply was expected to deteriorate in the spring.) Moreover, the rupture of internal trade has interrupted delivery of packaging materials, and loss of perishable crops has increased. These problems are compounded by inflationary pressures caused in part by the growth in food subsidies, which have now reached 12 percent of GDP. Increased procurement prices, effective since October 1990, will increase the subsidy bill by as much as 50 percent if retail food prices are not increased.

The visible worsening in the food economy comes paradoxically at a time when the grain harvest is exceptionally good (due to extremely favorable weather), estimated at approximately 220 million tons, compared with an average for the last five years of 204 million tons. This year's growing food shortages amid unusually abundant supply and dramatic increases in food subsidies illustrate the extent to which the chronic problems of the traditional command structure have affected the economy. The unusually large grain crop this year has muted the impact of the worsening price distortions and decline in the monetary economy; with a more normal grain crop, the crisis would be worse.

The problems in the food economy, although visible before, deepened in the 1980s. Growth in supply was modest despite continued high levels of investment in primary agricultural productive capacity. Growth in demand, fueled by increases in money wages of approximately 8 percent

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annually, continued to outpace growth in supply, resulting in worsening shortages. Despite a substantial increase in producer prices in 1983, an increasing number of farms experienced financial difficulties. In late 1989 the government announced a write-off of 73 billion rubles of farm debt, approximately half the balance of outstanding debt.

The chronic problems of the sector are rooted in the structure and incentives governing production, processing, and marketing. Over the last 25 years, growth in production has occurred under the centrally planned system, but at high budgetary costs and increasing forfeiture of opportunities to produce and consume other goods and services. Prices and costs have had little economic meaning, and the management of the sector has resulted in misallocation, waste, and destruction of the environment through overuse of inputs. Neither managers nor workers on state and collective farms have strong incentives to improve productivity, reduce costs, or preserve capital and land. Wages are standardized, and state quotas at fixed prices determine the allocation of resources. The price structure penalizes low-cost producers and those working in the small new private sector. Price subsidies for inputs have created chronic excess demand, and farm managers have little choice over quantities, quality, or timeliness of delivery. The state monopolies that supply inputs and process outputs have little incentive to serve either the farms' or the public's interest. If costs exceed earnings, the state usually offers financial relief either through the budget or the banks.

A number of partial reforms in farm organization during the 1980s brought little improvement and appear instead to have exacerbated some problems. The promotion of the collective contract, a team-based responsibility and compensation scheme, after 1985 encouraged producers to increase costs of production. The attempt to promote leasing in 1989 achieved little success because powerful collective and state farm chairmen opposed it, and the infrastructure necessary to serve small-scale leaseholders was lacking. With the visible worsening of the food economy, the Soviet government has agreed in principle to implement radical reforms in farm organization, ownership, and pricing, but important issues regarding the sequencing of the changes and their inclusiveness across the sector have not yet been resolved. Two important issues that remain controversial are liberalization of retail food prices and changes in property rights.

The prospects for success of a radical reform of the sector are favorable. The natural resource base of Soviet agriculture is rich; the people employed in agriculture relatively well educated and skilled; and the physical infrastructure, although inadequate, provides a foundation on which improvements can be made. The potential for growth in the sector is substantial through improving the use and allocation of currently committed resources. Moreover, agricultural growth may be achievable before improvements in industry are realized and may therefore provide early tangible evidence of the fruits of reform to a market economy. The agricultural reform depends, however, on successful liberalization of retail and producer prices and fundamental changes in property relations; each of these raises formidable political problems. The agricultural reform must thus include economic instruments necessary to improve the performance of agriculture and political and social policies needed to secure acceptance of these changes within the wider society. If the politics of agricultural reform, particularly the liberalization of retail food prices, can be managed successfully, the prospects for the transition throughout the economy will be much improved.

Pricing and Subsidies

Most agricultural and food prices at the retail, wholesale and farm level are controlled centrally. Retail prices for many foods have been held nearly constant since the early 1960s, whereas costs of production and procurement prices have risen substantially. Subsidies paid out of the budget to cover the difference between low retail prices and higher farm prices have increased dramatically and currently stand at 115 billion rubles. The growing

gap between official prices and free market prices makes it increasingly difficult for consumers to buy food through the state network, and costly alternative distribution networks, including barter trades, are displacing ordinary purchases of food. Procurement prices have traditionally been differentiated by geographic zones to cover average costs of production in the zone. An increasingly complex bonus system has refined cost-based zonal prices so that prices adjust to costs of production almost at the farm level. State orders have replaced production and sales quotas but remain functionally the same. Quotas and cost-plus pricing greatly reduce incentives to keep down costs of production and mask regional comparative advantage.

Producer Prices

Producers sell output for three kinds of prices: procurement, negotiated, and market. Procurement prices are established by the central government for specific products and are differentiated by geographic region. The procurement price consists of a base price plus a number of bonuses that depend on quantity, quality, and financial need. Weak state and collective farms receive price bonuses in an effort to improve their financial position. Private producers who market through the state usually receive base procurement prices without bonuses.

Most sales to the state in fulfillment of mandatory state orders (formerly sales plans) are made at procurement prices, including bonuses. State orders still cover a large portion of most commodities except potatoes and vegetables. Farms have been increasingly reluctant, however, to deliver products in fulfillment of state orders, and many orders were reported unfilled in fall 1990.

Two presidential decrees in October 1990 addressed the declining significance of state orders and the rupture of interenterprise linkages in the economy. The first stated that enterprises were legally bound to honor traditional supply relations, i.e., state orders. The second stated that wholesale prices for products delivered in fulfillment of traditional contractual relations could be renegotiated. More agricultural commodities can now be expected to be sold for negotiated prices, and these will be higher than procurement prices.

Negotiated prices prior to October 1990 were used primarily for (a) sales to the state of quantities in excess of state orders, and (b) direct interenterprise trade. The official consumer cooperative, Centrosouz, has traditionally been the major single purchaser at negotiated prices. Centrosouz buys from individuals or farms, processes, and resells at prices higher than state retail prices. Negotiated prices are determined in bilateral discussions between buyer and seller when the contract is written, or, after October 1990, renegotiated. Although the organization is formally a consumer cooperative, and individuals in rural areas buy shares to use its services, Centrosouz's activities have been highly regulated by the state, and shareholders have not participated in management.

Until October 1990, quantities of most commodities sold under negotiated prices were small. For potatoes and vegetables, however, all state orders were dropped in 1990, and all products sold either to the state or between enterprises move at negotiated prices. The state procurement price for potatoes in 1989 was on average 20 kop/kilo. Negotiated prices in early 1990 were reported to range from 35 to 55 kop/kilo, with higher prices appearing in the fall when the potato harvest was uncertain. Negotiated prices generally fall between procurement prices and free market prices.

Products sold directly to consumers on the free or collective farm market move at market clearing prices. Local councils have authority to enforce price ceilings, but do so only in exceptional cases, because it is widely expected that prices on the collective farm markets will be higher than in state outlets. Sellers must market their output directly; no paid

**Table 1. Average Received Procurement Prices
(rubles per ton)**

	World prices 1989 \$1MT	State & collective farm				From individuals			
		1986	1987	1988	1989	1986	1987	1988	1989
Grain	201 (Wheat)	172	173	205	220	NR	NR	NR	NR
Oilseeds	275 (Soy)	305	475	505	535	NR	NR	NR	NR
Sugar beets		56	57	56	58	NR	NR	NR	NR
Flax		1804	2089	1555	1773	NR	NR	NR	NR
Potatoes		181	176	190	213	178	180	200	198
Vegetables		221	231	236	244	366	389	396	394
Melons		116	122	114	126	93	97	103	114
Fruits		350	374	396	421	385	356	366	328
Grapes		446	448	461	485	528	531	518	482
Tobacco	2134	4642	4359	4069	4895	4898	5031	4852	6182
Tea	2020	915	948	1174	1152	862	862	1149	1124
Beef	2570	2550	2645	2975	3128	1979	1948	2090	2207
Mutton		1774	2045	2349	2839	2297	2272	2559	2849
Pork		2164	2219	2506	2643	2293	2292	2327	2470
Poultry		2135	2198	2283	2377	2009	2625	3754	3586
Milk		425	429	525	553	309	321	336	324
Eggs		97	98	98	97	68	68	68	68
Wool		9296	9476	11086	11964	8151	8240	8297	8436
Silk cocoons		8673	8289	8176	8928	10603	10871	10729	9212
Cotton	1670 ^a	770	781	841	923	NR	NR	NR	NR

NR Not relevant. No purchases from individuals.

a. World price for cotton is quoted for cotton fiber. Soviet price is for seed cotton. Fiber is approximately 32 percent seed cotton by weight in the U.S.S.R.

Source: State Committee on Food and Procurement, U.S.S.R.; World Bank, International Economics Department, International Commodity Markets Division.

intermediation is allowed. An individual who does not want to market his or her product directly must sell through the local state or collective farm, or turn to *Centrosoiuz*. In 1989 the small-scale cooperatives that constitute the growing private sector in industry, trade, and services were explicitly denied the right to trade in food, although they can still engage in public catering. Sales on collective farm markets are usually in small lots, and the costs of retailing are high.

Until October 1990, state procurement prices and state orders dominated farm level prices, and these were the best indicators of actual prices received for most commodities. Average procurement prices for major commodities for 1986-89 and new prices announced in fall 1990 are shown in table 1. World reference prices are also shown for 1989, although the available data do not allow quality comparisons. The Soviet farm level prices in late 1990 (taking into account the doubling of grain prices in May 1990 and other increases in October 1990) embody an implicit exchange rate of approximately 2.5 to 3 rubles to the dollar.

The increase in procurement prices in 1990, although substantial, will have limited impact on producers' incentives to supply. With the declining monetization of internal trade and the rise in barter, higher prices have reduced appeal. Moreover, the average prices conceal a wide range of variation around the mean, and more efficient producers in areas with comparative advantage in a particular commodity receive considerably less than the national average price. For example, although the national average price for milk in 1988 was 525 rubles per ton, producers in Lithuania and Estonia received 371 rubles per ton, and producers in Russia received on average 644 rubles per ton.

The current multiple exchange rates and restrictions on convertibility make it difficult to compare domestic prices with world prices. With a tourist exchange rate of 6 rubles to the dollar, the official rate at 1.8 rubles to the dollar, and the auction rate at approximately 20 rubles to the dollar, few producers, given the choice, would sell output domestically at 2.5 to 3 rubles to the dollar. The extent to which the current price structure taxes producers, however, cannot be judged by looking at nominal rates of protection, or even effective rates of protection. Explicit subsidies on fertilizer and machinery have been discontinued, but prices are still low except at the greatly overvalued official exchange rate. Furthermore, the price system has in the past been only one way in which farms received resources. Flows through the budget and the banking system under the old system are functionally inseparable from flows through prices.

Retail Prices

Food products in the Soviet Union are sold through three channels: state retail stores, state-dominated cooperative markets, and farmer markets. Retail prices are fixed in the state stores, negotiated and administratively controlled in the cooperative markets, and free in the farmer markets. About 70 percent of food consumption normally derives from purchases from state retail outlets, including distribution through special channels at official prices. Approximately 25 percent of retail trade in food moves through the highly controlled cooperative stores at prices higher than those in the state stores. The remaining 5 percent of retail trade (by value) moves through the farmer markets at market prices.

Retail prices for food products sold through state retail trade are set centrally and differentiated for three broad geographic zones of the country. These prices have been changed little since the early 1960s, although there have been substantial increases for particular items, such as alcohol, fruits, and coffee, and introduction of new products with higher prices. State prices vary little seasonally and do not adequately capture the different qualities of the same basic commodity, for example, beef of different cuts.

Table 2. Sales of Food on Urban Collective Farm Markets

	000 tons						% total trade in food by volume					
	Bread	Potatoes	Vegetables	Meat	Milk	Eggs	Bread	Potatoes	Vegetables	Meat	Milk	Eggs
1940	766	2038	1371	722	1972	1233	4.4	44	37	41	27.6	42
1950	3166	6606	1442	826	2278	1489	16.4	69	44	39.1	24.3	49
1955	1977	5875	1631	721	2549	3163	8.1	67	35	22.2	17.7	56
1960	1649	5102	1272	537	1648	3161	6.2	58	24	9.9	6.5	37
1965	1312	4552	1038	499	1251	2169	4.3	47	15	7.8	3.8	17
1970	1240	4644	1106	498	970	2057	3.8	43	13	5.9	2.1	11
1975	886	4313	1281	475	757	1239	2.5	35	12	4.2	1.4	3.8
1980	1159	4875	1415	492	705	1242	3.1	38	11	4.3	1.2	3.1
1981	1101	4537	1544	470	687	1256	2.9	37	11	4.1	1.2	3.0
1982	1059	4695	1560	465	670	1265	2.8	35	11	4.0	1.2	2.9
1983	1606	4912	1519	482	637	1242	4.1	34	10	3.9	1.0	2.8
1984	1700	4943	1567	462	627	1221	4.3	34	10	3.5	0.9	2.6
1985	1887	4654	1562	439	607	1175	4.8	34	10	3.2	0.9	2.5
1986	1224	4749	1822	467	573	1179	3.2	32	11	3.3	0.8	2.4
1987	1436	4731	1984	485	538	1291	3.7	32	13	3.2	0.7	2.6
1988	1480	4681	2113	512	555	1160	3.8	34	13	3.1	0.7	2.3

Source: Goskomstat SSSR, *Torgovlia SSSR*, *Finansy i statistika*, Moscow, 1989, p. 315.

Higher prices generated on the parallel market and the growing shortages in state stores have put pressure on official retail prices. Many consumers indirectly pay more than official prices for food purchased in state stores, although these additional costs rarely are recorded in family budget surveys. Some of the higher cost is in household time allocated to searching and waiting in lines for food. Direct and indirect payments and reciprocal favors to clerks and store managers raise the real cost of subsidized food, as do tied sales and quality degradation. For most commodities in many localities, the actual prices that consumers effectively pay in state outlets fall somewhere between official and parallel market prices.

Retail trade in food is also conducted through Centrosiuz at administered prices. Although formally a consumer cooperative, Centrosiuz functions to a large degree as an outlet of the state retail trade network. Centrosiuz operates most retail stores in rural areas and also has outlets in some urban areas. Approximately 25 percent of retail trade in food passes through the cooperative network (23 percent when aggregated at state prices). Centrosiuz buys directly from farms and households, processes (e.g., into sausage, jam, cheese), and resells either to peasants or urban people. If the raw materials in the product were purchased at state procurement prices, then Centrosiuz is supposed to resell the processed product at state retail prices and is subsidized for the difference. If the raw material was purchased directly from households or from farms at negotiated prices, the product can be sold at a higher price.

As a consequence of the pricing policy of Centrosiuz and its dominance in retail trade in rural areas, most food products in rural stores have higher prices than in urban areas, and farm families travel to the city to buy back the food they produced. For example, meat in state stores costs approximately 2 rubles/kilo, when it is available. In the cooperative stores it is approximately 5 rubles per kilo, and in the collective farm market from 8 to 20, depending on market conditions and excess demand.

In 1989 the central government relinquished control of producer and retail prices for potatoes and vegetables, and it stopped paying a subsidy from the central budget. State orders were retained, to be filled at negotiated prices. Local councils received authority to regulate retail prices if they so chose and to pay a subsidy from their own funds. Potatoes and vegetables were thus subjected to a hybrid form of price regulation, and the effects of the mix in the 1990 season were quite damaging. Local councils have imposed price ceilings but have limited funds to pay a subsidy. Consequently, they have pressured producer prices to levels at which it is in some cases uneconomical to harvest and transport the crops. The new form of price regulation has combined with poor harvest weather and a shortage of drafted labor traditionally used to bring in the crop and has complicated the 1990 potato and vegetable harvest.

The delegation of retail price regulation to local councils and removal of the centralized subsidy are contributors to the current problems in potato and vegetable trade. They could easily recur with other commodities if local councils have authority to impose retail price ceilings.

In addition to the administered channels of state stores and cooperatives, consumers can also buy food at market prices at the collective farm market. Meat and many other food commodities are available there even when state stores are empty. These markets are important indicators of changes in market conditions, because they are the only fully legal parallel markets with flexible prices. For most commodities, however, they are very thin markets, and a small proportion of total volume flows through them, as shown in table 2. In 1988, they handled a significant volume only of potatoes (34 percent of trade by volume), vegetables (13 percent by volume), and fruits. Only 3.1 percent of all meat was sold in the free market. The relative importance of free markets varies geographically; they tend to carry a higher proportion of total trade in food in the Ukraine and southern cities

**Table 3: Food Subsidies: U.S.S.R.
(billions of rubles)**

	1960	1965	1970	1975	1980	1985	1990 ^a	1990 %	1970-80	1980-85	1985-90
Meat	1.4	2.8	8.8	12.2	14	26.6	48	50.1	1.4	6.6	12.5
Fish	0.1	0.2	0.2	0.2	0.2	2.1	3.1	3.2	0.0	26.5	8.1
Milk			2.1	4	7.5	18.9	31	32.3	6.5	9.7	10.4
Grain		0.3	0.8	0.6	0.8	4.4	7.3	7.6	2.9	18.6	10.7
Potatoes			0.2	0.7	1.4	3	4.4	4.6	7.2	7.9	8.0
Sugar						1	2.1	2.2			16.0
Total	1.5	3.3	12.1	17.7	23.9	56	95.9		3.6	6.9	11.4
Percentage of state exp.	2.1	3.2	7.8	9.2	8.1	14.5	18				

a. Budgeted subsidy for 1990 was 95.9. Actual expenditures are estimated at 115 billion rubles, due to producer price increases at mid-year.

Source: Ministry of Finance, U.S.S.R.

than they do in Russia and the northern areas. In Odessa, 28 percent of marketed meat was sold in 1988 on the collective farm market, whereas in Moscow only 0.5 percent of meat (by volume) was sold through the collective farm markets. Approximately 5 percent of total trade in food has moved traditionally at free prices through the collective farm markets. When all trade in food is aggregated at official state prices, the relative share of collective farm markets falls to about 2 percent.

The acute shortages of the past year have brought increasing numbers of more affluent consumers to collective farm markets. The proportion of trade in food that passes through the collective farm market had been declining since World War II, but the recent worsening shortages have increased trade in some commodities. Data for the period January-June 1990 show a 15 percent increase in sales of pork on collective farm markets, compared with the first half of 1989, and a 29 percent increase in mutton, but much smaller increases in other products and declines in several products.

Budgetary Subsidies

In the 1980s, the increasing difference between higher procurement prices and nearly constant official retail prices led to a substantial and growing direct budgetary subsidy from the central government. In 1990, the subsidy was budgeted at 95 billion rubles, but in fact cost 115 billion rubles, or approximately 12 percent of GNP. The procurement price increases announced in October 1990 will add to the subsidy, but when and by how much depend on decisions on retail prices. The subsidy now is contributing to the deterioration in the monetary economy and the eroding value of the ruble. Its increase or maintenance at current levels is inconsistent with the stabilization program that must be part of the transition.

The large and growing subsidy has many deleterious effects on the agricultural economy. Agriculture, through the subsidy, both contributes to and is victimized by the growth in the monetary overhang and the deterioration of the ruble. Agricultural producers, unsure that they will be able to dispose productively of rubles, withhold sales in favor of either costly barter trades or additions to inventory. The growing wedge between official prices and market prices generates large economic rents and corresponding activities to capture the rents, such as the reported increased presence of organized crime in wholesale trade in food. Excess demand shows up immediately in food markets, depleting shelves in grocery stores and pushing up prices on the free market. Consumers are less aware of the improvement in aggregate per capita consumption that has taken place since 1985 (according to official data, shown in table 3) than they are of the increasing shortages and difficulties in obtaining food.

The growing subsidy and unwillingness to raise retail prices have thwarted much needed improvements in the quality of food sold and the service embodied in the final good. The transition in food marketing that would have been expected to accompany income growth and urbanization over the past two decades did not happen. The backwardness of food processing and retailing is a direct consequence of retail price policy. All costs of delivering a more highly processed, better marketed product must be borne by the budget as long as retail prices are immovable, and this has proven an effective brake on investment in food processing.

Low retail prices and uncertain supply at those prices encourage consumers and public caterers to keep excessive inventories, with resulting increase in waste. The traditional locus of payment of the subsidy stimulated waste. Processors paid for raw materials at a low price that already included the subsidy, and therefore could write off waste and loss at a low price. This pricing policy encouraged diversion of product to the black market, and not all waste was actually lost. A decision to require processors to pay the higher price for raw material and receive a subsidy only for the actual volume that survives processing was taken several years ago, but never implemented.

Table 4. Food Consumption by Republic Per Capita (kilograms)

	USSR	RUS	UKR	BEL	UZB	KAZ	GRU	AZE	LIT	MOL	LAT	KIR	TAD	ARM	TUR	EST
Meat																
1970	48	50	49	49	29	50	31	26	72	35	70	38	30	34	38	73
1980	58	62	61	61	31	56	43	32	81	49	76	38	32	47	44	82
1985	62	67	66	70	31	58	47	35	87	54	85	40	31	49	41	89
1988	66	73	69	72	30	60	50	38	87	55	85	48	30	53	43	82
Milk & dairy in milk equivalent																
1970	307	331	311	371	150	265	235	227	464	172	453	172	126	328	135	420
1980	314	328	331	369	185	275	309	281	415	265	483	177	164	432	174	453
1985	325	344	350	399	180	260	309	293	409	294	455	182	152	433	168	489
1988	356	386	367	421	201	300	337	306	441	304	455	253	164	457	208	478
Eggs (pieces)																
1970	159	182	156	170	73	122	85	90	208	128	194	81	44	94	58	241
1980	239	279	239	294	90	206	135	134	253	183	259	108	79	146	87	305
1985	260	299	276	315	107	217	148	155	285	209	295	124	104	148	92	296
1988	275	319	286	326	117	226	162	165	319	219	294	142	120	169	101	294
Fish																
1970	15	19	16	14	3	9	6	3	15	12	21	6	3	4	4	29
1980	18	22	17	16	4	10	8	3	17	14	2	6	3	4	5	25
1985	18	22	18	20	5	11	9	5	18	13	24	6	3	5	5	25
1988	18	22	18	20	5	10	8	4	19	14	23	6	3	6	4	25
Sugar																
1970	39	42	41	35	21	34	35	33	37	33	46	30	23	26	25	44
1980	44	47	52	43	22	38	45	40	41	47	46	33	24	31	25	46
1985	42	45	46	44	22	37	43	37	43	45	47	32	25	29	27	45
1988	47	50	50	49	24	44	48	41	50	50	51	38	30	33	29	49
Vegetable oil																
1970	7	7	7	5	8	5	3	2	4	11	7	5	8	2	5	7
1980	9	9	10	7	10	8	5	2	6	10	9	7	10	3	8	9
1985	10	10	10	8	11	10	8	3	8	12	9	9	11	2	8	9
1988	10	10	11	8	12	11	5	2	7	13	8	9	11	3	9	8
Potatoes																
1970	130	139	156	245	28	94	38	25	212	75	146	59	33	55	23	151
1980	109	118	133	200	29	86	46	25	150	75	128	56	35	55	23	122
1985	104	109	139	185	26	89	49	28	134	79	122	65	35	65	31	113
1988	99	107	122	173	28	84	50	27	143	67	117	66	32	60	24	109
Vegetables																
1970	82	82	103	70	66	66	51	47	86	84	82	60	65	101	84	80
1980	97	94	115	77	116	84	79	72	78	115	72	74	95	118	105	83
1985	102	98	124	81	107	90	87	62	84	129	80	98	91	135	111	79
1988	101	97	125	85	97	92	98	65	84	129	76	86	86	156	109	82
Bread																
1970	149	144	165	144	160	150	195	155	113	187	110	144	173	154	159	112
1980	138	126	146	140	177	147	190	160	111	177	107	149	177	140	165	96
1985	133	119	138	131	177	146	190	158	107	173	104	144	178	134	168	92
1988	131	117	138	129	167	139	184	155	111	173	107	139	170	131	163	87

Source: Goskomstat SSSR, *Torgovlia SSSR*, *Finansy i statistika*, Moscow, 1989, pp. 24-25.

An effort to change the locus of the subsidy payment contributed to uncertainty in meat marketing during 1989 and 1990 and may have accounted for some reduction in deliveries of meat to the all-union fund (commodities that enter trade through central allocation). Republics delivering meat to the all-union fund were traditionally reimbursed for the full cost of the subsidy incurred during processing. During 1989 efforts to shift the cost of the subsidy from the all-union budget to the republic budgets of the place of consumption began. The discussion of whether the union budget or that of the locality of consumption should pay the food subsidy is complicated and not yet resolved. Funds in late 1990 were still flowing from the central budget for this purpose, but the discussion raised the possibility that republics and provinces exporting meat beyond their borders might have to absorb the cost of the subsidy themselves.

The huge food subsidy exceeds government expenditures for health and education, and its growth has probably contributed to the relative decline in these areas (expenditures for health and education in 1987 had expanded by 48 percent since 1976-80, whereas food subsidies had risen by 170 percent). The safety net of social welfare programs--including unemployment insurance for the unemployed and welfare for the marginally employed--that will be needed during the transition will be difficult to finance unless the pressure of agriculture on the budget is relieved.

The food subsidy has been considered by many a substitute for an explicit safety net to meet the nutritional needs of vulnerable consumers. How well has the subsidy served the interests of the poor? Approximately half of the total subsidy is delivered through one commodity (meat), and a quarter is delivered through milk and other dairy products. The distribution of consumption of these two highly subsidized commodities reveals much about the distribution of the food subsidy among income groups and geographic regions and demonstrates its regressive nature.

Data on the regional distribution of per capita consumption of meat and milk are presented in table 4. Throughout the country, per capita consumption of highly subsidized commodities is greater in urban than in rural areas, and is higher in richer than in poorer areas. This is not surprising, because meat has a high income elasticity. Furthermore, the subsidy is greatest for products sold in state stores, and these stores are located predominantly in urban areas. The geographic distribution of the subsidy clearly favors the richer republics over the poorer, and richer urban consumers over poorer rural consumers. State employees are reported to pay on average 2.6 rubles per kilo of beef, whereas collective farm households pay on average 3.9 rubles per kilo. Almost one-third of all meat sold in state and cooperative trade is consumed in cafeterias, restaurants, schools, and other outlets of public catering and predominantly serves the urban population. State employees spend on average 12 percent of their food budget in public catering, whereas collective farm families spend just over three percent.

More refined data (not yet available) are needed to assess the degree to which urban poor people have access to subsidized meat and milk. Access is likely to differ between regions that are net exporters of meat and those that are net importers. Evidence from Lithuania, a republic with high production and consumption of meat (a net exporter of meat), indicates that meat consumption rises with income, and that urban people with higher incomes pay somewhat more for meat than do those with low incomes (see table 5). Even in Lithuania, however, where the urban poor have much better access to subsidized meat than do poor people in the rest of the U.S.S.R., the meat subsidy is regressive: those with higher incomes receive more subsidy than do the poor. The same is true for dairy and for all subsidized food in Lithuania: per capita consumption and the subsidy rise with income class. Evidence from other regions of the U.S.S.R. that are net importers of meat also suggests that higher-income people pay less per unit for meat because they have better access to the trade channels through which subsidized meat is distributed.

Table 5. Per Capita Meat Subsidy in Lithuania by Income Group, 1987

Per capita monthly income (rubles)	State employees				Collective farm members			
	Annual consumption kg	Expenditure	Unit price	Estimated per capita meat subsidy ^a	Annual consumption kg	Expenditure	Unit price	Estimated per capita meat subsidy ^a
75	57	110.13	1.93	232	65	149.39	2.30	n.a.
75-100	71	164.73	2.32	261	62	176.51	2.36	n.a.
100-125	71	156.98	2.21	269	68	158.37	2.33	n.a.
125-150	82	185.69	2.26	307	73	185.69	2.54	n.a.
175-200	87	207.20	2.38	315	72	199.13	2.77	n.a.
> 200	98	254.45	2.60	333	84	262.74	3.13	n.a.

a. Assuming state expenditures of approximately six rubles per kilo. Estimated subsidy for collective farm members is not calculated, because proportion of purchases from subsidized sources is unknown.

Source: Tsentral'noe Statisticheskoe Upravlenie Litovskoi SSR, "Biudzhety rabochikh, sluzhashikh, i kolkhoznikov po grupпам semei s razlichnym razmerom srednedushhevo go sovokupnogo dokhoda za 1986g"; Vilnius, 1987.

Agroindustry

Deficiencies in transport, storage, processing, and distribution of food and fiber result in high losses, which are estimated at about 20 to 30 percent of production for some crops. Grain loss is approximately equal to total imports. For potatoes and vegetables losses are estimated to be as high as 40 to 50 percent. Soviet sources estimate that about 1 million mtms of meat are lost annually through inadequate cold storage and obsolete slaughter and processing facilities, a figure about equal to the level of annual imports of meat. Although figures on losses may be exaggerated to mask diversion of production into uncontrolled marketing channels, actual waste is high. In the sugar refining industry, for example, extraction could be greatly improved and losses reduced considerably. The Soviet Union produces about 8.5 million tons of sugar from a total beet crop of close to 100 million tons, i.e., the aggregate extraction rate is about 9 percent, whereas the sugar content of beet is, on average, around 15 percent. With fewer losses during transport, improved storage facilities for beets, and better refining technologies, the aggregate extraction rate could rise by 3 to 4 percentage points, i.e., 3 to 4 million tons of sugar, which approximates the present level of Soviet imports of about 5 million tons of sugar annually.

Investment in the food industry in the U.S.S.R. has been consistently low. Only about 15 percent of total investment in the agricultural and agroindustrial sector has been allocated to processing industries (see table 6). Two-thirds of processing equipment is obsolete and worn out, with much of the machinery dating back to the 1950s and 1960s. The current annual replacement rate is only 5 percent, and two-thirds of processing enterprises need retooling and renovation. The Soviet authorities recognize the need to invest more in food processing industries and in the transport and storage sectors. By reducing the presently high level of losses, investment in food processing and storage should be more productive than investment in agricultural production. Future investment in food processing, however, must be guided by investment criteria appropriate for a market economy and cannot be undertaken before the foundations for the market are in place.

To speed up modernization and development of the processing sector, the defense industries have been asked to transform part of their capacity to provide more and higher-quality processing equipment. In addition, a program to improve the food industries, worth Rbs. 77 billion rubles, was adopted in 1988. It is scheduled to run until 1995 and includes spending on storage facilities. Half of the funding is to be spent on processing machinery and the remainder on plant and storage. If fully implemented, it would mean a doubling of the annual average rate of investment in the processing sector over the 1988 level.

To date, the program has met with limited success. Expenditure on the food processing sector is running several billion rubles behind schedule. Bilateral credits granted to the Soviets to import and to improve food processing technology have been only partly used. The Soviet capacity to absorb foreign technology appears to be limited. Furthermore, the program to divert resources from the defense industry to nonmilitary production has met resistance from the defense industry itself. Overall, the commissioning of new processing capacity has been lagging behind schedule since 1988, and the priority intended for food processing has thus far not been realized.

The Soviet Union has traditionally imported agricultural inputs and machinery and equipment for the food industry from Eastern Europe and CMEA countries. Half of these imports were from the former German Democratic Republic. The value of imports from the OECD area of (a) food processing machines and parts; (b) machinery for cleaning, filling, closing, etc.; (c) bottles, cans, and parts; and (d) refrigerating equipment and parts (SITC 727, 74522, 74523, 7414) accounted for only \$463 million in 1989. This figure is

Table 6. Capital Investment in the Soviet Economy and in Agriculture

	Total investment in the Soviet economy (rbs. bn.)	Investment in agricultural production in rbs. bn.			Share of investment in agricultural production in total investment in the economy (in percent)	Investment in rural housing and rural infrastructure		Agricultural production and rural infrastructure investment in the economy (in percent)
		By state budget	By collective farms	Total		(rbs. bn.)	Share in total investment (in percent)	
-----Annual averages-----					-Annual average-			
1956-60	36.5	2.38	2.96	5.34	13.9	1.04	2.7	16.6
1961-65	55.9	4.72	3.74	8.46	15.1	1.82	3.3	18.4
1966-70	79.7	8.10	5.24	13.34	16.7	3.46	4.3	21.0
1971-75	112.6	14.38	7.86	22.24	19.8	4.64	4.1	23.2
1976-80	143.5	29.46	9.18	28.64	20.0	6.10	4.5	24.5
1981-85	168.6	21.86	9.38	31.24	18.5	9.68	5.7	24.2
1986	194.4	23.00	10.50	33.50	17.2	12.40	6.4	23.6
1987	205.4	23.80	10.60	34.40	16.7	12.80	6.2	22.9
1988	218.2	24.60	11.90	36.50	16.7	12.50	5.7	22.4

Source: Accounted according to Narodnoe khoziaistvo, SSR, Vol. 1987g, Moscow, 1988, pp. 240, 249, 294; and Narodnoe khoziaistvo SSSR, Vol. 1988g, Moscow, 1989, pp. 435, 551.

low when compared with total food imports from the hard currency area, amounting to \$9 billion in the same year.

At present, most of the processing capacity is located in urban areas, close to consumers and to sources of labor. This frequently leads to high losses because the raw material must be transported over long distances on bad roads.

One of the main reasons for the inefficiency and slow progress in investment is related to the centralized command system. Fixed state orders and distorted prices leave little room for managers to decide on production and investment or to specify the kind of equipment they require to improve efficiency. Controlled low retail food prices mean that investments in food processing are not recoverable through normal commercial transactions and must be carried directly on the budget. Managers traditionally have avoided retooling and have sacrificed product quality in favor of continued delivery of quantities necessary for state orders. Furthermore, controlled prices rarely take into account transport costs or seasonality; as a result, agroindustry is mislocated and incentives to store commodities are weak.

Additional investment in food processing, storage, and transport is not sufficient by itself to remedy the high loss and waste in the current system. Much of the waste can be attributed to price distortions. New investment criteria are needed to make future investments in food processing more productive than those of the past investments. Most of the expansion of food processing in the future will take place in the private sector and will be funded by commercial loans from private banks. Thus price liberalization and reform of the financial sector should precede significant new investment in food processing and storage so that the investments are more productive than were past commitments.

State and Collective Farms

State and collective farms are the major organizational forms of Soviet agriculture. Prior to the reforms of the 1960s, state and collective farms differed significantly, but changes in wage policy, pricing, and investment policy have eroded these differences. In addition, many unprofitable collective farms have been reorganized as state farms, further blurring the distinction between the two.

Both land and assets of the state farm are owned by the state. Workers on state farms are salaried employees of the state and have rights to the benefits available to state employees. Wages are determined according to a standardized scale and depend little on the financial performance of the farm. State farm workers, as employees of the state, have always had rights to internal passports and could therefore freely travel within the country and seek new employment. The budget takes profits and losses of the state farm and provides most investment. State farms are free to hire labor and face the same restrictions on dismissal as do other state enterprises.

Collective farms are not state enterprises and are governed by a different set of regulations. Historically collective farm members, as a separate legal class of Soviet citizens, had different rights than did employees of the state. Prior to 1974 they did not have the legal right to internal passports (although many did obtain passports), and their geographic and professional mobility was correspondingly restricted. Collective farm members jointly own the assets of the farm except for land, which the state owns. The labor on collective farms is provided by members. The farms cannot hire labor, with the exception of trained specialists and managers, few of whom would be willing to give up the higher status and benefits of state employees to become members of collective farms. Prior to the wage reforms of 1966, earnings of collective farm members were determined as the residual after all other obligations had been met. Residual earnings depended on quotas and prices over which farms had little influence, and wages of

collective farm members prior to the changes in 1966 averaged approximately one-third those of state employees in all sectors.

In 1966 collective farms were urged to adopt the wage tariff of the state farms and to take on short-term debt to cover the wage bill if necessary. Collective farms were given access to sources of investment from the budget and banks already available to state farms. Purchase prices for state and collective farms were standardized. Because collective farm members had never had much influence in farm management, the changes of the 1960s removed most differences between collective and state farms. Highly profitable collective farms were able to retain more of their earnings than did profitable state farms, and collective farms were somewhat more free to engage in subsidiary, nonfarm activities. As the agricultural sector enters the transition to a market economy, few differences between state and collective farms remain.

Employees of state and collective farms have the right to farm a subsidiary plot. The size of the plot varies geographically, with the availability of land. The maximum size under existing legislation is 0.5 hectares per family, but very few households farm a plot that large. In the U.S.S.R. as a whole, one-fifth of collective farm households manage a private plot greater than 0.4 hectares. Plots are largest in the Baltic republics and smallest in Central Asia. Most plots in Russia, Belorussia, and the Ukraine are between 0.25 and 0.5 hectares. The private plot is used for livestock products, potatoes, and fruits and vegetables for marketing and own consumption. Because the plots are very small, most feed comes from the state or collective farm. Families use the plots very intensively for products with high value added. That private plots contribute half of the production of potatoes and fruits and approximately a quarter of meat, milk, eggs, wool, and vegetables from 3 percent of the planted area reflects both the greater efficiency of the private plots and their use for labor-intensive, rather than land-intensive activities, such as grain, oilseeds, and sugar.

A number of partial reforms of state and collective farms have been attempted in recent years, with little success. The most debilitating characteristics of the organization are poor labor incentives, limited managerial autonomy, and weak financial discipline. The introduction of the collective contract brigade in the early 1980s was an effort to improve labor discipline and incentives by linking wages of a small group of workers to the measured performance of the group as a whole. Measurement problems and the lack of stronger financial discipline caused costs of production to rise as workers used the new system to increase their wages. The introduction of lease contracting in 1987 and its official endorsement in 1989 were intended to create opportunities for private enterprise within the state and collective farms. Few farm workers took out leaseholds; farm managers did not in general encourage leasing, and the marketing relations of traditional collectivized agriculture were not supportive of private small-scale farming.

The organizational structure of Soviet farms at the outset of the transition to the market, therefore, has changed little from that of the late 1960s: large collective fields and herds, tiny household plots, rigid wages, poor labor discipline, weak financial discipline, and little farm autonomy. Efforts to introduce marginal changes in this structure have failed. The evident weakness of this organizational form provides the argument for full-scale privatization.

Privatization in agriculture involves four kinds of assets: land, machinery and farm structures, agroindustrial facilities, and housing. To preserve equity in the distribution of the state's assets, privatization of agricultural assets must be consistent with the strategy chosen for the economy as a whole. Equity criteria, vaguely defined but nonetheless essential to sustainability, are likely to be violated if terms of the agricultural privatization are markedly different from those governing other sectors. Therefore, the strategy to privatize the rural areas has to be

considered within a general strategy for the economy as a whole, particularly with respect to agroindustry and rural state-owned housing. There are particular elements in the privatizing of land, however, that make the issue of land reform and denationalization much more political and difficult. In late November 1990 the Russian republic adopted legislation sanctioning private ownership of land, but restricting sales. Under the new law, a private owner who wants to divest of land can resell only to the local government. Emergence of a land market will be severely constrained if this provision is retained in the future.

The government's economic program announced on October 19, 1990, entails minimal changes in farm organization. Collective and state farms that are financially viable will not be reorganized. Bankrupt farms will be restructured as cooperatives, deeded over as subsidiary enterprises of industrial plants, or divided among people who want individual farmsteads. The envisaged changes would thus leave the most productive Soviet farm assets under an intact, old system of management. Reorganization of the approximately 25 percent of farms that are weak or bankrupt might reduce the budgetary burden of these expensive producers if the reorganization is substantial.

If the government's plan were to be implemented and to succeed, the agricultural sector after the transition would consist of large state and collective farms differing little internally from current ones, except that they would be expected to be financially viable. People who live and work on the more prosperous farms would have little opportunity to express their preferences with regard to the future of state and collective farms. A private sector somewhat larger than today's would continue to function around the margins of the collective sector. This minimalist approach to farm reorganization in the published program appears to belie the more radical rhetoric of the need for fundamental change in farm organization.

The conservatism in the October 1990 program reflects the strength of the lobby of managers of large state and collective farms, the absence of a forum through which rank and file workers on financially stronger farms can express and explore their views on the issues, and the reluctance of many workers on these farms to take on the risks of entrepreneurship in a hostile environment. A minimalist or gradualist approach may be the choice of many agricultural workers, but they have not yet been given a real choice. An alternative approach would be to enfranchise workers on state and collective farms by granting them shares of the farm lands and assets and to give those who so choose the right to manage their shares separately, even if the parent farm is not bankrupt. This approach would give workers who prefer the security of collective management the option to retain it. It would enhance the democratic character of the reorganization by reducing the power of farm chairmen to determine its course.

Land reform raises several issues:

Should the collectives be treated differently from the state farms? Under existing law, members of collective farms formally have a claim on the assets of the farms--excluding land--whereas the workers of the state farm have no such claim. This claim could complicate reorganization or privatization in several ways. Managers and workers who oppose privatization could block the process by claiming that the state cannot tell them what to do with their own assets and could thereby thwart the wishes of those who would like to operate separately.

With the quixotic price policy of the past and repeated debt forgiveness, the argument that collective farms own something that state farms do not is weak. In the six decades since collectivization, the physical boundaries of farms have been changed several times, and collective farms have been converted to state farms. This aspect of history will of necessity affect the land-to-labor ratios on individual farms, but the arbitrary

designation of state and collective farms need not influence future patterns of resource use.

Members of both state and collective farms could be given the opportunity to choose either to remain in a restructured cooperative farm or to take their share of the farm's assets and work independently. The state can decree that employees of state farms have this choice, because it owns all the assets and can fully determine their disposition. The decree could also be binding for collective farms.

In the Baltic republics, collectivization was relatively recent and the previous owners more easily identifiable. In Lithuania, a political decision has been adopted to return land to prior owners or their heirs if they claim it. Similar provisions have been discussed in East European countries, notably Hungary, but not adopted. Claims of prior owners complicate privatization of remaining assets by clouding title to land potentially claimable, but not yet claimed. Prior owners should be given a deadline to present their claims, after which remaining land could be redistributed. Those who receive land through privatization must have uncontested title to it.

Should land be privately owned or leased from the state? Public ownership of land still has many adherents, even among those who recognize the inefficiency of collective management. Restrictions on ownership carry economic costs.

If the state retained ownership of land, but transferred ownership of assets to collectives, the farms would become autonomous production cooperatives. Members would have incentives to manage their assets better, but would be restricted in disposition of a major asset--land. Opportunities for individual enterprise would be limited. Moreover, experience in other countries indicates that efficient agricultural production cooperatives are rare. If this form of organization is imposed on the sector, it will be for ideological reasons, and not because the empirical record indicates that it works.

Leasing could be made almost equivalent to individual land ownership if three conditions are met:

- Use rights should be granted for a long period, and enforceable fines for destroying the productive potential of land should be established;
- Use rights should be transferrable, through inheritance, sale, or donation. The transferability should include the possibility of mortgaging the leasing title;
- Use rights should also be divisible, that is, the lessee should be able to split the leasing title--without the consent of the lessor--and transfer one or several of the parts. This is essential to give to the market on rights the same flexibility that the markets on land have.

If these three conditions are met, marketable user rights conveyed through leaseholds would be functionally equivalent to ownership, although leaseholders would probably have less confidence in their tenure than they would if they were owners. The market value of a leasehold would depend on the established rental fee.

How should access to services and markets be ensured? Private farmers, whether owners or leaseholders, need access to markets for inputs and output. Some essential services are provided by organizations off the farms: trade organizations that distribute the inputs and buy some of the outputs; the processing plants, which constitute the primary market for many farms; and

the banking system. Many services not available today, such as transportation for hire, storage, and private insurance, would appear in a market economy.

Privatization of economic units outside the farms should proceed according to guidelines for the relevant sector. The commercial enterprises should be privatized as part of the service sector, and service monopolies dismantled. Processing plants should be privatized under the rules relevant to the industrial sector. A paramount objective in restructuring services and processing should be creation of a competitive environment: transfer of public monopolies into private hands will not necessarily improve the economic environment for small-scale producers.

Many services are now provided on farms. These include the storage and local distribution of inputs (gas stations, fertilizer storage and distribution), veterinary and agronomic advisory services, the collection and storage of output, and provision of machinery and transport services. The severance of services from the farms that now hold them is important in the creation of a competitive environment and assurance of wide access to inputs and machinery. To help ensure that services would not be restricted from access by other farms, cooperative farms should not have the option to keep services inside the farming cooperative, at least in the early part of the transition. Nor should farming cooperatives be allowed to buy up the assets of service cooperatives if the purchase would reduce competition in services. Once administrative boundaries between farms are removed and services are separated from exclusive use by one farm, competitive supply of services would increase and cooperative farms may then purchase their own equipment. Producers dissatisfied with one provider could turn to the neighboring farm for service or purchase their own machinery. The creation of service cooperatives is important because it will take years for machinery appropriate for smaller-scale production to become widely available. In the interim, productive use of current machinery must be continued through leasing or contracting of services.

Subsidiary service activities of farms can be privatized in several ways:

- They can become specialized cooperatives delivering, services such as land preparation and harvesting and providing fuel and other inputs. Membership in the cooperative should be open and the bylaws of the cooperative should ensure transparent access to the services of the cooperative;
- They can be organized as joint-stock companies delivering specialized services. As such, they would abide by the laws governing other firms in the economy, including regulation of monopoly behavior;
- Their assets can be sold at auction to private farmers, other service cooperatives, or individuals wishing to specialize in certain services. Some private farmers may voluntarily purchase large pieces of machinery, together or individually, for later rental to others.

Credit and Investment

Attempts to modernize Soviet agriculture, through direct investments and subsidies to encourage farms to invest their own funds, have so far resulted in disappointing growth rates in production and have placed an increasing burden on the state budget. The share of investment in agriculture has remained consistently high in recent years, yet production has stagnated or increased only very slowly. The agricultural sector's contribution to GDP remains below its share of investment, and the return to capital is low.

**Table 7. Outstanding Debts of State and Collective Farms
(billions of rubles)**

	1968	1970	1980	1985	1986	1987	1988
Total	5.4	19.4	100.0	139.4	144.7	148.0	144.3
of which							
Long-term debts	2.4	10.8	42.4	57.1	60.2	61.0	62.7
of which							
State farms	-	0.5	8.4	9.7	11.0	11.6	15.2
Collective farms	2.4	10.3	34.0	47.4	49.2	49.4	47.5
Short-term debts	3.0	8.6	57.6	82.3	84.5	87.0	81.6
of which							
State farms	2.3	6.1	31.9	45.8	46.2	47.6	46.5
Collective farms	0.7	2.5	25.7	36.5	38.3	39.4	35.1

Source: Narodnoe khoziaistvo SSSR, Vol. 1988g, Moscow 1989, p. 629.

Credit and Banking

State-allocated credit has been widely used to bail out inefficient and high-cost producers. Under this system, state and collective enterprises belonging to the agroindustrial complex have accumulated an ever-growing debt which, in mid-1990, accounted for over 60 percent of all outstanding long-term debt (see table 7).

Postponing interest rate payments and credit repayments has become a common practice for many state and collective farms, inevitably resulting in the transfer of short-term credits into long-term credits or the writing-off of a large part of the outstanding farm debt altogether. That debt forgiveness is necessary despite very low interest rates for agricultural credit is evidence of low rates of return to capital, because interest rates are below the current rate of inflation. At present, the following interest rates apply on credits to the agricultural sector: (a) long-term loans (up to 30 years or 10-15 years)--0.75 percent (b) short-term loans (one year)--collective farms, 1 percent; state farms, 2 percent; and processing industry, 3 percent. These rates rise to 3 to 5 percent in the farm sector for rescheduled credits. Substantial increases in interest rates are scheduled for 1990, but these will still lag inflation, resulting in negative real rates.

Stricter credit conditions and more financial discipline are being introduced. The Agricultural Bank (Gosagrobank [GAB]), the major credit institution for the agricultural and agroindustrial sector and the largest bank in the country, was converted (September 14, 1990) into a joint stockholding company, which has set an authorized share capital of Rbs. 8 billion. The Soviet Ministry of Finance is the biggest single shareholder, accounting for 32 percent of the initial equity capital. Altogether there are about 4,000 shareholders, mostly state or collective farms and enterprises, local authorities, and a few individuals. The bank plans to build up its own deposit base for reimbursing its sizable debt at the State Bank. GAB employs 90,000 people and has 3,500 branches (offices) and about 160,000 clients, out of which about 50,000 are state and collective farms.

Prior to its conversion, GAB had a portfolio of Rbs. 298 billion. The liability side of the balance sheet consisted of some 45 billion of client deposits, of which about Rbs. 3 billion were own capital, and 253 billion were loans from the State Bank. On its conversion to a stock company, Rbs. 73 billion of bad loans were written off. Further write-offs are expected, including some to be decided at the republic level. These write-offs are resulting in a simultaneous reduction in the bank's loan portfolio and in its debts toward the State Bank. The bank's initial capital of Rbs. 8 billion would, under present regulations (which stipulate that capital must not exceed 20 times shareholder funds), provide scope for a loan portfolio of Rbs. 160 billion. After the expected further write-off of bad loans, the bank expects a balance sheet total of Rbs. 130-140 billion, leaving further scope for expansion of Rbs. 20-30 billion.

Prior to its conversion, GAB operated on a net interest margin of some 0.25 percent, earning on average an interest rate of 1.75 percent on its loan portfolio and paying, on the liability side, an average rate of 1.5 percent. In January 1991, it planned to increase lending rates on short-term credits to 6 percent and on long-term credit to 9 to 12 percent. GAB claims that it would need a net profit margin of 4 to 5 percent to be competitive and to improve its office equipment, particularly in the field of telecommunications.

This conversion of the agricultural bank to a joint shareholding company has consequences for the management and role of the new bank. It is doubtful that GAB has currently sufficient capacity and capability to deal with the credit needs of the agricultural and agroindustrial sector under a market economy. In the past, credits that were given to large state and

collective farms and enterprises did not require any detailed evaluation, because defaults on repayment were automatically passed on to the state budget. With the possible emergence of a large number and variety of smaller agricultural cooperatives and private farms, and the need to impose a strict financial discipline in the interest of its shareholders and economic efficiency, GAB will need to build up its credit analysis and evaluation capacity considerably to serve a new and very different rural clientele. It will not wish to expose itself to overly high risks, in particular as long as land is not privately owned and cannot be used as collateral. The financial services of the GAB will need to be complemented with alternative forms of credit facilities, such as credit cooperatives and credit unions which have proved to be very successful in other countries. Technical assistance in establishing these alternative lending and savings institutions will be needed.

GAB is prepared to continue as the government's intermediary for the implementation of special lending programs for specific target groups or sectors, e.g., individuals or cooperatives taking over land and assets from insolvent state or collective farms or farms that could survive in the new conditions. Credits for these purposes would have to be based on a careful evaluation of the capacity to restructure to economically profitable units and may require a subsidy during the transition to cover GAB's transaction costs of dealing with many more smaller clients requiring technical evaluation.

A major concern will be the ability of the newly privatized GAB to respond adequately to the enormous demands for credit that will be placed upon it to meet the private investment needs of the rural areas. No longer purely an outlet for government investment, this bank (and the other banks) will now be aiming at a more commercial approach to lending that will, at least in the short term, reduce their capacity to deliver credit. This could lead to a major contraction of investment at a time when investment should be strongly maintained if sector growth is to be sustained. This situation has to be monitored carefully by the state so that remedial and transitional arrangements can be put into place if production is seriously affected.

Public Investment

Investment in agriculture has currently (1986-89) been running at some 65 billion rubles/year, about 30 percent of the U.S.S.R.'s annual investments. The main investment issues are (a) the efficiency of the allocation of these resources; (b) the amount of the allocation to different subsectors; (c) the source of funds for investment; and (d) the needed institutional arrangements for guiding, monitoring, and evaluating investment policy.

Data indicating approximate allocation of investments are shown in table 8. Investment in agricultural production includes investment in tractors, harvesters, and ancillary agricultural equipment, as well as equipment for livestock and localized irrigation, such as central pivot and on-farm pumped schemes. Rural infrastructure covers access roads to and within farms, social infrastructure such as housing, water and gas systems, and in some cases medical clinics and schools. Agroindustry and storage represent the diverse subsectors of the food processing industry, including cereals, feed and sugar processing, as well as fruits and vegetables and alcoholic beverages. Large-scale irrigation and drainage covers investment in large schemes, which are mainly supported by the all-union budget, particularly in Central Asia and the Volga River region (irrigation) and the more extreme northwestern part of the country (drainage).

Investment in agriculture has, in the last decade, mainly been directed at on-farm machinery and inputs. Rates of investment in farm equipment and machinery have remained fairly steady in real terms over the last 15 years (see table 8), typically absorbing some 60 percent of all investments. There has been a significant increase, however, in investment in

rural infrastructure as measured by GOSPLAN, with an increase, again in real terms, of 150 percent between the late 1970s and the mid-1980s, reaching some 22 percent of all sector investments. Investment in agroindustry and storage has, nevertheless, remained steady at a relatively low rate of 10 percent of the investment program throughout the same period (see table 9), and investment in irrigation and drainage peaked in the late 1980s before falling back sharply in the last two years (see table 10).

Although there has been an overall increase in the rate of investment in rural infrastructure in the last 15 years, inadequate rural infrastructure is consistently cited as a factor preventing normal farming operations and contributing to the poor quality of life in the rural areas. Access to farms during the critical harvesting period is often difficult, particularly in the more northern areas where the growing season is short. In many years, and 1990 was the most recent example, many crops remain unharvested because of problems with access and transportation. Telecommunications and other facilities essential for the introduction of a more liberal marketing regime remain underdeveloped except in the major urban centers.

Inadequate attention has been paid to economic and environmental matters on large-scale irrigation and drainage schemes, with funds being wasted on "grandiose schemes," causing costly and irreparable damage to the environment. Although the achievements in the irrigation program have been impressive, with a doubling of the area under irrigation to some 22 million hectares since 1966, the development of farming in newly equipped irrigation and drainage schemes has lagged, and the desired benefits from this investment have not been fully realized. The situation is reportedly worse in the drainage schemes of the northwest than in the irrigated areas of the south, but the problem is widespread. Also of concern is the shortage of quality materials and spare parts to support the construction program in irrigation because of inadequate allocation by the central planning authorities. This has led to the use of substandard materials in some cases (such as poorer quality polyethylene for drainage pipes with inadequate filter materials, leading to early clogging). The result has been severe maintenance problems and underperformance in some completed works.

In the irrigation subsector, needed reforms in investment have already started. At the beginning of the 1980s large irrigation and drainage schemes accounted for some 15 percent of all investment in the sector and reached a peak in 1987 of 9.4 billion rubles. This figure has since fallen to 12 percent as a new emphasis on more economic investments has been introduced and major potential "white elephants" shelved. The need to make more progress on improving output from completed investments, however, remains urgent.

A general problem facing government authorities in evaluating projects is the extremely distorted prices established by government controls. Priorities and returns to investment lose meaning in such an environment, especially given that world market prices provide poor guidance when the official or even market exchange rate is meaningless and distortions so rampant that even estimates of a shadow exchange rate are impossible.

The capacity of government to finance the investment program in agriculture has suffered from increasing pressures to cut expenditures and reduce budget deficits. Recently, the central union budget has tended to diminish, and more spending authority is being passed on to the republics. This has, however, only led to the creation of increased budget deficits at the republic level. Part of the problem has been the inability of the government to use the banking system to mobilize funds for investments through loans that are reimbursed by borrowers. Debt forgiveness has become so commonplace that the banks lending to agriculture emerged as cash transfer agents for government funds rather than real banks. This has eliminated discipline from the financial markets and thus the ability of the banks to participate in investment.

**Table 8. U.S.S.R. Investments in Agriculture
(billions of rubles)**

	1976-80 average/ year	1981-85 average/ year	1986-89 average/ year
Investment in agricultural production	28.6	31.2	35.0
Rural infrastructure	6.1	9.7	12.5
Agroindustry and storage	5.3	5.2	6.8
Large-scale irrigation	8.0	8.7	8.9
Total	48.0	54.8	63.2

Note: 1984 prices.

Source: GOSPLAN, Vodstroj, VASKhNIL, Narodnoe khoziaistvo SSR 1987, Moscow, 1988, pp. 435, 561.

**Table 9. U.S.S.R. Investments in Agroindustry and Storage
(billions 1984 rubles)**

	1976-80 average/ year	1981-85 average/ year	1986-89 average/ year
Food industry	1.3	1.0	1.3
Meat and dairy	0.8	0.8	1.2
Fish industry	1.0	1.2	1.4
Feedmills	0.8	0.9	1.0
Forestry production	0.3	0.2	0.3
Village stores	1.0	1.2	1.7
Total	5.3	5.2	6.8

Source: VASKhNIL.

Table 18. Investments in Irrigation and Drainage through Vodstroj, 1966-98
(billions of 1984 rubles)

Year	Total	Civil works	Village infrastructure	On-farm investments
1966	2,326	1,915	172	-
1967	2,732	2,220	212	-
1968	3,391	2,745	270	-
1969	3,644	2,881	307	-
1970	4,166	3,286	357	-
1971	4,483	3,369	373	120
1972	5,225	3,871	429	132
1973	5,687	4,512	490	137
1974	6,531	4,874	585	141
1975	7,486	5,588	583	175
1976	7,636	5,652	706	191
1977	7,876	5,412	746	229
1978	7,936	5,372	787	270
1979	8,301	5,541	818	274
1980	8,251	5,460	866	264
1981	8,136	5,422	911	292
1982	8,210	5,713	1,007	280
1983	9,060	6,208	1,034	314
1984	8,784	5,994	1,083	279
1985	8,764	6,051	1,162	287
1986	9,212	6,414	1,229	422
1987	9,359	6,487	1,306	498
1988	9,191	6,350	1,354	689
1989	7,923	4,720	1,277	1,196
1990	7,947	n.a.	1,633	n.a.

Source: Vodstroj.

Finally, a major problem has been the weakness of the institutions responsible for ensuring that investment funds are used in a way that meets the government's criteria for acceptable investment. This is illustrated by the major "white elephant" schemes of the past, such as the costly Kara-Kum canal project (and others, often in the industrial sector), and by the evident weakness of the agriculture bank to carry out the rigorous financial analysis necessary to test the viability of projects supported by it.

The restructuring of the banking sector, combined with the gradual privatization of the land and the creation of autonomous farms, should enable the banking sector to provide a major new source of funds for agriculture that will gradually take the pressure off the state and republican budgets. Current plans are to limit union spending to 15 percent of the investment budget with the balance to be taken up by the republican budgets and the banks; this seems to be a realistic objective. On the key institutional side, however, there is a vital need to introduce and apply strict investment criteria for union and republican investments to bring about the needed upgrading in investment efficiency.

There is an urgent need--and a new opportunity--to improve investment efficiency. This will be greatly facilitated by the proposed move to a market economy because the real value to the economy of proposed investments can be more readily determined. However, this improvement will not be achieved unless the institutions responsible for guiding and authorizing investments play a much more active role in evaluating investments to ensure they meet minimum economic and financial criteria. Criteria for the acceptability of investments at union and republican levels and by the banks need to be established and a process of independent review of investments put in place. Also, training courses need to be introduced for key staff with the objective of upgrading project and investment analysis in the key public and banking institutions.

A shift of investment from the farm to downstream storage and processing is required because the current waste of agricultural products suggests that major returns can be gained from reducing losses. However, funds for these investments will be strongly offset by the need for investment funds of newly privatized farms, which will have to purchase machinery more adapted to operating on smaller farms. The rate of this new on-farm investment will depend on the speed of the privatization of farming and the extent to which foreign exchange can be made available to finance the required imports for investment. Indeed, the rate of restructuring that can be achieved in the sector may, in the short term, be limited by the rate at which imported equipment can be made available to the rural sector because Soviet industry seems ill equipped at present to deliver substantial quantities of needed on-farm and agroindustrial equipment. Relaxation of import controls and more liberal policies regarding the establishment of foreign machinery suppliers and the import of the spare parts required to maintain this equipment will become just as important as making the necessary funds available. Privatizing industries that produce farm machinery will also assist in accelerating the production of new models more suitable for private agriculture.

Expansion of rural infrastructure will need to be a priority in public investment. This will require a new analysis of objectives and priorities in the restructuring of rural areas. New district-level plans need to be prepared to capture the most urgent requirements in the coming years, but given the backwardness of many rural areas, the process of investment could well be lengthy and costly. A continuous commitment to improvement must be maintained for many years for such a policy to bear fruit. However, an immediate need that will have to be reviewed is the building of rural markets so that local trade can take place. In the irrigation subsector the current policy of concentrating on the achievement of better production and benefits from existing schemes appears to be correct and should be maintained. A full technical and economic assessment of all major existing schemes should now be

carried out to determine the measures required to optimize these benefits under the new economic conditions. This could, for example, lead to changes in land use in these areas and to some focused investments to provide for better productivity (for example, drainage and canal rehabilitation). Direct investments by farms or farmers in local irrigation schemes should still be encouraged where they are shown to be economically and financially viable.

Agriculture in the Context of the Larger Transition

Management of the agricultural transition will be critical to the success of the larger economic transition. Food is very visible and highly political. People think about it every day, and their assessments of the food situation spill over to general attitudes about the state of the country. The fragile support for the economic transition will be confused and eroded by the sense in major Soviet cities--evident at the beginning of 1991--that the food economy continues to deteriorate with no comprehensive national program to arrest the decline.

A reasonably well-managed agricultural transition is a precondition for achieving the political and fiscal stability necessary for the Soviet economy to move forward out of its current crisis. Soviet citizens and the international community have much to gain from successful integration of a growing Soviet Union into the world economy. The contributions of both will be necessary to make it happen.

FROM PLAN TO MARKET IN CHINESE AGRICULTURE

Justin Yifu Lin, Richard Burcroff II, and Gershon Feder

One of the Chinese government's accomplishments is its ability to feed over one-fifth of the world's population with only one-fifteenth of the world's arable land. When the People's Republic of China was founded, cultivated land per capita was only 0.18 hectare. Because of rapid population growth, per capita cultivated land dropped to 0.1 hectare in 1978, yet the government was able to keep food production ahead of population growth. The economy also experienced a dramatic transformation: the share of industrial income in total national income expanded from 12.6 percent in 1949 to 46.8 percent in 1978 (SSB 1987a, p. 11). Remarkable achievements in Chinese agriculture, however, did not occur until the recent farm sector reform launched in 1979, which replaced the original collective system with a new household farming system.

Between 1952 and 1978, the growth rate in grain production was 2.4 percent per year, only 0.4 percent above the population growth rate during the same period. Per capita availability of grain, therefore, increased only 10 percent over a quarter of a century (table 1). Frustrated by the inability to raise living standards substantially 30 years after the socialist ascent to power, Chinese leaders in 1979 initiated a series of sweeping reforms in agriculture, resulting in extraordinary agricultural growth in the first half of the 1980s.

The success of agricultural reform, especially the remarkable growth of grain output, induced an additional series of market-oriented reforms, which were undertaken at the end of 1984 in both the urban and rural sectors. Although agriculture as a whole grew at a respectable average annual rate of 4.1 percent after 1984, grain production stagnated after peaking at 407 million tons in 1984 (table 1). Over the many dynastic transitions in the several thousand years of Chinese history, political leaders in China have come to recognize the crucial importance of food production to political and social stability. Therefore, the optimism that robust agricultural development generated during the first five years of rural reforms was swiftly replaced in the subsequent downturn by pessimism.¹ There has even emerged a call for recollectivization of the individual household-based farming system under the banner of pursuing economies of scale in agricultural production. China's agricultural reform is at a crossroads.

This paper analyzes the problems that the reforms intended to remedy, the achievements obtained, and the issues that remain to be resolved.²

Development Strategy and Collectivization

The agricultural problems prior to the 1979 reforms stemmed from the development strategy that the Chinese government adopted in the early 1950s. The postreform problems also have their roots in the early development strategy.

To strengthen national power as the economy was recovering from wartime destruction, China adopted in 1952 a heavy-industry-oriented

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Table 1. Population, Agricultural Output, and Grain Output in China

Year	Population (millions) (1)	Agric. output (1952 = 100) (2)	Grain output (million tons) (3)	Grain trade ^a (million tons) (4)
1952	574.8	100.0	163.9	1.5
1953	588.0	103.1	166.8	1.8
1954	602.7	106.6	169.5	1.7
1955	614.7	114.7	184.0	2.1
1956	628.3	120.5	192.8	2.5
1957	646.5	124.8	195.1	1.9
1958	659.9	127.8	200.0	2.7
1959	672.1	110.4	170.0	4.2
1960	662.1	96.4	143.5	2.7
1961	658.6	94.1	147.5	-4.5
1962	673.0	99.9	160.0	-3.9
1963	691.7	111.5	170.0	-4.5
1964	705.0	126.7	187.5	-4.7
1965	725.4	137.1	194.6	-4.0
1966	745.2	149.0	214.0	-3.6
1967	763.7	151.3	217.8	-1.7
1968	785.3	147.6	209.1	-2.0
1969	806.7	149.2	211.0	-1.5
1970	829.9	166.4	240.0	-3.2
1971	852.3	171.4	250.2	-0.6
1972	871.8	169.6	240.5	-1.8
1973	892.1	183.8	265.0	-4.2
1974	908.6	190.1	275.3	-4.5
1975	924.2	196.0	284.5	-0.9
1976	937.2	195.3	286.3	-0.6
1977	949.7	194.3	282.8	-5.7
1978	962.6	210.2	304.8	-7.0
1979	975.4	226.0	332.1	-10.7
1980	987.1	229.2	320.6	-11.8
1981	1,000.7	244.0	325.0	-13.6
1982	1,015.9	271.5	354.5	-14.9
1983	1,027.6	292.6	387.3	-11.5
1984	1,038.7	328.5	407.3	-7.2
1985	1,050.4	339.7	379.1	1.2
1986	1,065.3	351.2	391.5	-0.1
1987	1,080.7	371.6	403.0	-8.9

a. Positive figure indicates net export, and negative figure indicates net import.

Source: SSB 1988, pp. 97, 38, 248, 730, 737; Ministry of Agriculture, Planning Bureau 1989, pp. 147-49, 520-22, 534-35.

development strategy. The goal was to build as rapidly as possible the country's capacity to produce capital goods and military materials.

The government assumed that through low wages the state-owned enterprises would be able to create large profits and to reinvest the profits for infrastructure and capital construction. The practice of establishing low prices for energy, transportation, and other raw materials, such as cotton, was instituted for the same reason.³

To implement the policy of low wages, the government was required to provide urban dwellers with inexpensive food and other necessities, including housing, medical care, and clothing. A strict food rationing system was instituted in 1953 and is still in effect. Meanwhile, to secure the food supply for rationing, a compulsory grain procurement policy was imposed in rural areas in 1953. The grain trade in China has been virtually monopolized by the state since then.

The industrial development strategy also resulted in a great demand for agricultural products. Because the government was reluctant to divert resources from industry to agriculture, the core of the agricultural strategy involved mass mobilization of rural labor to work on labor-intensive investment projects, such as irrigation, flood control, and land reclamation, and to raise unit yields in agriculture through traditional methods and inputs, such as closer planting, more careful weeding, and the use of more organic fertilizer. The government believed that collectivization of agriculture would facilitate these functions. Collectivization was also viewed as a convenient vehicle for effecting the procurement of grain and other agricultural products to carry out industrial development strategy. After several phases, the well-known commune was established nationwide in the late 1950s. The average size of a commune was about 5,000 households with 10,000 laborers and 4,047 hectares of cultivated land. Payment in the commune was made according to both subsistence needs and the work performed. Work on private plots, which existed in the other forms of cooperatives, was prohibited.

Despite dramatic increases in modern inputs in the 1960s and 1970s, the performance of agriculture continued to be poor. The total factor productivity in the 1970s before the reform in 1979 reached only about three-fourths of that in 1952. Although self-sufficiency was greatly emphasized, China changed from a net grain exporter in the 1950s to a sizable grain importer after 1962 (table 1). The primary cause of the poor agricultural performance before the 1979 reform was the inadequate incentive structure in the collective system (Lin 1988).

Rural Reforms in China

In 1978 China started a series of fundamental reforms in the rural sector that reversed agriculture's disappointing performance. Output growth accelerated to a rate several times the long-term average in the previous period. The annual growth rates of the three most important crops--grain, cotton, and oil-bearing crops--averaged, respectively, 4.8 percent, 17.7 percent, and 13.8 percent between 1978 and 1984, compared with the average annual rates of 2.4 percent, 1.0 percent, and 0.8 percent in the preceding 26 years. For the cropping sector and agriculture as a whole, growth was equally impressive: average annual growth rates rose from 2.5 percent and 2.9 percent to 5.9 percent and 7.4 percent (table 2). In 1985, China became a net grain exporter, the first time after a quarter of a century (table 1, column 4).

The dramatic output growth was a result of a package of reforms that reduced the functions of ideology and plans and gave priority to the roles of individual incentives and markets. Broad changes in rural policy began at the end of 1978. The importance of providing enough incentives to farmers to break the bottleneck of agricultural production was recognized.

Table 2. Average Annual Growth Rates of Agricultural Output (percent)

Year	Agric. output value	Crop output value	Grain output	Cotton output	Oil crops output	Population
1952-78	2.9	2.5	2.4	2.0	0.8	2.0
1978-84	7.4	5.9	4.8	17.7	13.8	1.3
1984-87	4.1	1.4	-0.2	-12.9	8.3	1.3

Source: Ministry of Agriculture, Planning Bureau 1989, pp. 112-15, 146-49, 189-92; Ministry of Agriculture 1989, pp. 28, 34 (internal document); SSB 1988, p. 97.

Price Reform

The most important policy change, originally intended by the government to occur at the beginning of the reforms, was the adjustment of procurement prices for major crops. Before the reform, two distinct prices, quota prices and above-quota prices, existed in the state commercial system. Quota prices applied to crops sold in fulfillment of procurement obligations, above-quota prices to crops sold in excess of the obligation. Announced at the end of 1978 and implemented in 1979, quota prices increased 20.9 percent for grain, 23.9 percent for oil crops, 17 percent for cotton, 21.9 percent for sugar crops, and 24.3 percent for pigs (SSB, Trade and Price Statistical Division 1984, pp. 404-06 [internal document]). In addition, the premium paid to the above-quota delivery of grain and oil crops was raised from 30 percent to 50 percent of the quota prices, and a 30 percent bonus was instituted for above-quota delivery of cotton.⁴

Corresponding to the increase in procurement prices, retail prices were raised significantly. As compensation, each urban dweller was given ¥5-8 a month. Consequently, government price subsidies increased. The financial burden became especially unbearable when the unexpected output growth started to emerge in 1982. The price subsidies increased from 8.4 percent of the state budget to 24.6 percent of the state budget in 1984 (SSB 1988, pp. 747, 763). To reduce the state's burden and to increase the role of markets, the mandatory procurement quotas were abolished (for cotton in 1984 and for grain in 1985) and replaced by procurement contracts that were to be negotiated between the government and the farmers. The contract price was a weighted average of the basic quota price and above-quota price. This change resulted in a 9.2 percent decline in the price margin paid to farmers (table 3). However, following the decline of grain and cotton production in 1985 and stagnation thereafter (table 3), the contracts became mandatory again in 1986 (Sicular 1988a).

Institutional Reform

Unlike the price reform, the change in the organization of farming from the collective system to the household-based system, now called the household responsibility system, was not intended by the government to occur at the beginning of the reforms. Although it had been recognized in 1978 that solving the managerial problems within the production team system was the key to improving low incentives, the official position at that time maintained that the production team was to remain the basic unit of production management and accounting. Subdivision of collectively owned land and production management delegation to individual farm households were considered the reverse of the socialist principle and were thus prohibited. Nevertheless, toward the end of 1978, a small number of production teams, first secretly and later with the blessing of local authorities, began to test the system of

Table 3. Price, Cropping Patterns, and Cropping Intensities

Year	State above-quota/ contract price (1978 = 100) (1)	Household responsibility system (%) (2)	Sown area		
			Grain crops (%) (3)	Cash crops (%) (4)	Other (%) (5)
1965	84.1	0	83.5	8.5	8.0
1970	97.2	0	83.1	8.2	8.7
1971	98.4	0	83.1	8.2	8.7
1972	98.4	0	81.9	8.5	9.6
1973	98.1	0	81.6	8.6	9.8
1974	98.4	0	81.4	8.7	9.9
1975	98.7	0	81.0	9.0	10.0
1976	99.4	0	80.6	9.2	10.2
1977	100.0	0	80.6	9.1	10.3
1978	100.0	0	80.4	9.6	10.0
1979	140.7	1	80.3	10.0	9.7
1980	140.4	14	80.1	10.9	9.0
1981	145.1	45	79.2	12.1	8.7
1982	144.3	80	78.4	13.0	8.6
1983	144.9	98	79.2	12.3	8.5
1984	142.5	99	78.3	13.4	8.3
1985	129.4	99	75.8	15.6	8.6
1986	130.1	99	76.9	14.1	9.0
1987	130.2	99	76.8	14.3	8.9

Source: Column 1 is from Lin 1989b. Column 2 indicates the percentage of production teams in China that had adopted the household responsibility system. The data for 1979-81 are from *Jingjixue Zhoubao* (Economic Weekly) 1982. Figures for 1982-84 are from Editorial Board of China Agricultural Yearbook 1984, p. 69; 1985, p. 120. Figures for 1985-87 are inferred from the fact that there was no major change in the farming institution since 1984. Columns 3 to 5 are from Ministry of Agriculture, Planning Bureau 1984, p. 132 (internal document); 1989, pp. 130-31, 355-57 and SSB 1988, pp. 224, 243, 276.

contracting land, other resources, and output quotas to individual households. A year later, these teams brought in yields far larger than those of other teams. The central authorities later accepted the existence of the new form of farming but required that this practice be restricted to the poor agricultural regions, mainly the hilly, mountainous areas, and where teams had lost confidence in the collective. This restriction, however, was ignored by most regions. Full official recognition of the household responsibility system as a universally acceptable mode of farming institution was eventually given in late 1981, two years after the initial price increases. By that time, 45 percent of production teams in China had already dismantled and had instituted the household responsibility system. Thus, the shift in the institutional structure of Chinese agriculture essentially evolved spontaneously in response to underlying economic forces (Lin 1987).⁵ By the end of 1983, 98 percent of production teams in China had adopted this new system (table 3, column 2).

When the household responsibility system was originally introduced, the collectively owned land was leased to each of the households in a team for one to three years. Along with the land lease was a contract between the household and the team, specifying the household's obligations to fulfill state procurement quotas and to pay various forms of local taxes. A household could, however, retain any product above the stated obligations. In

the distribution of land leases, equity was the general guiding principle. Therefore, collective land was usually leased to households in proportion to their size, without considering the interfamily differences in the size of labor force (Kojima 1988). This pattern of land allocation inhibited efficient land use. At the initial distribution, moreover, land was first classified into several different grades, and then households were allocated a parcel from each grade. As a result, a household's holding on the average is fragmented into nine tracts, although the size of the holding is only about 0.5 hectare. The initial one- to three-year short contract provided inadequate incentives to invest in land improvement and soil-fertility conservation. Consequently, several new policies were introduced: (a) in 1983 households were allowed to exchange labor with other households and to employ a limited amount of labor for farm work (Kueh 1985); and (b) in 1984, for the purpose of providing better incentives for soil conservation and investments, leaseholds were extended to 15 years.

The national policy still stresses the importance of maintaining institutional stability of the newly established household farming system. However, the doctrine of equating farm machinery with advanced technology and large farm size with efficiency is still deeply rooted in the minds of many Chinese scholars and leaders (Ash 1988). Because of the increasing concern regarding the stagnation of grain production after 1984, calls for recollectivization have reemerged, under the guise of enlarging operational size to exploit returns to scale. In some places, this has resulted in contract disruption before expiration without the consent of farmers (Jiang 1988). Thus, farmers may possibly be deprived of the increasing economic independence they have enjoyed during the past 10 years (Johnson 1989).

Market and Planning Reform

The third most important element of the reform is the greater role given to markets, in place of planning, for guiding production in the rural sector. The prevalence of planning in agriculture before the reforms was a result of self-sufficiency in grain, a component of the heavy-industry-oriented development strategy that the Chinese government began to pursue in 1952. Because state grain procurement prices were depressed at an artificial level, the more grain an area exported, the more tax it paid. Areas with comparative advantage in grain production were therefore reluctant to raise the level of grain output. Consequently, grain-deficit areas had to increase grain production if grain demand increased as a result of growth in population or income: national self-sufficiency degenerated into local self-sufficiency. Thus, to guarantee each region would produce enough grain for its needs, agricultural production planning was extensive. Mandatory targets often specified not only sown acreage of each crop but also yields, levels of inputs, and so forth. Because grain was given priority in the planning, insufficient attention was paid to economic considerations. To increase grain output to meet state procurement quotas and local demands, the local government was often forced to expand grain-sown area at the expense of cash crops and to increase cropping intensity, although these practices often resulted in a net loss to farmers. Such measures undoubtedly caused a misallocation of land, and the inefficiency was especially serious in areas that traditionally depended on interregional grain trade to facilitate the specialization in cash crops.

The loss of allocative efficiency caused by the self-sufficiency policy was conceded at the beginning of the reforms. Although planning was still deemed essential, more weight was given to market considerations. The decision to increase grain imports, cut down grain procurement quotas, and reduce the number of products subjected to planning reflected this intention. Moreover, restrictions on interregional trade for agricultural products by private traders were gradually loosened (Sicular 1988b). Special measures were also taken to encourage areas that traditionally have comparative advantages in cotton production to expand cotton-sown acreage.

All of the above policy changes reduced the role of direct state planning intervention and increased the function of markets in guiding agricultural production. As a result, cropping patterns and cropping intensities changed substantially between 1978 and 1984, largely in conformity with comparative advantage. The area grown to cash crops increased from 9.6 percent of total sown acreage in 1978 to 13.4 percent in 1984, a 41.6 percent increase in relative terms.

The climax of the market was the declaration at the beginning of 1985 that the state would no longer set any mandatory production plans in agriculture and that obligatory procurement quotas would be replaced by purchasing contracts between the state and farmers. The restoration of household farming and the increase in market freedom prompted farmers to adjust their production activities in accordance with profit margins. The acreage sown to cash crops further expanded from 13.4 percent of total sown acreage in 1984 to 15.6 percent in 1985, while the grain-sown acreage declined from 78.3 percent in 1984 to 75.8 percent in 1985 (table 3). The expansion in animal husbandry, fishery, and subsidiary production was even faster. As a result of these adjustments, agricultural output still grew at a respectable rate of 3.4 percent in 1985. Nevertheless, the aggregated outputs of the cropping sector declined 1.9 percent. Among the three most important crops, the output of grain declined 6.9 percent and cotton declined 33.7 percent; only oil crops registered a 33.3 percent increase in 1985. The stagnation of the cropping sector lingered after 1985 (table 3). The 1990 grain output is at a record level (about 3 percent over the 1984 level), but it is widely believed to be attributed to extremely favorable weather conditions and possibly the reimposition of administrative interventions in acreage decisions. This apparently led to a drop in efficiency because yields have declined.

In the early 1980s the market-oriented reforms had aroused concerns among some policymakers over "loss of control" (Sicular 1988a). In light of the unprecedented success between 1978 and 1984, the promarket group was able to push further for market orientation. However, when the growth rates slowed down and grain output declined in 1985 and thereafter, the government retreated from its 1985 position. The voluntary procurement contract was made mandatory again. Formally, the policy announced in 1985 was reversed in 1990. Throughout the period 1985-90, administrative intervention in market and production has been increasing.

These three components of reforms definitely contributed positively to the remarkable output growth between 1978 and 1984. A careful econometric analysis, using province-level input-output data covering the period 1965-87 and employing a production function approach, found that of the 42.2 percent output growth in the cropping sector in 1978-84, 43.6 percent can be attributed to productivity growth due to reforms. Of the productivity growth, 94 percent is attributable to the changes in farming institutions from the production team system to the household responsibility system, and the remaining 6 percent to the combined effects of increases in prices and changes in cropping patterns and cropping intensities. The last two items are related to reforms in the role of markets and planning (Lin 1989b).

International Agricultural Trade

Foreign trade is an integral part of China's national economic planning. During the 1980s, China's agricultural foreign trade system continued to be highly administered, showing large real distortions between domestic and border prices for the more important traded commodities (see the following chart). However, procurement for export at administered quota prices and sales of imports at the urban ration prices, considerably lower than free market prices, accounted for the bulk of commodities traded. Thus, the effective price relatives were considerably more distorted than a comparison of free market and border prices would indicate. The official exchange rate was overvalued in 1988 and remains so at this writing. When

Ratio of Rural Free Market to Border Prices, 1987-88

	Exchange rate		Shadow 1988
	Official 1987	1988	
Milled rice at unit export price	1.09	0.90	0.51
Wheat at unit import price	n.a.	1.50	0.85
Corn at unit import price	1.10	0.98	0.56
unit export price	1.30	1.08	0.61
Soybeans at unit import price	1.13	n.a.	n.a.
unit export price	1.18	n.a.	n.a.

valued at a shadow exchange rate of, say, ¥6.5/US\$1.00, 1988 rural free market prices were only between 51 percent (rice) and 85 percent (wheat) of the corresponding border prices. This comparison implies that tremendous economic rents are accruing to the state in the exportation of rice and corn. Similarly, huge economic subsidies are being absorbed in the importation and marketing of imported wheat and corn.

China's imports and exports of grain and animal products continue to dominate the country's agricultural foreign trade. During the 1980s, China joined the United States, EEC, and U.S.S.R. as a dominant force in the international grain economy. China is now the world's largest producer of grains, accounting for nearly 20 percent of the world's output in recent years. With 22 percent of the world's population, China is also the largest consumer of agricultural products. By the end of the 1980s, China had become responsible for more than one-third of the world's rice production and utilization, about 20 percent of its wheat, about 15 percent of its maize, and as a producer, more than 10 percent of the world's soybeans and one-third of the world's total feed grains.

Land, Labor, and Input Markets

The reforms outlined in the preceding sections address important aspects of the agricultural economy, but other areas remain restricted, thus maintaining a considerable degree of inefficiency. These involve the incomplete liberalization of the land market, the constraints on labor mobility, and the nonmarket production and allocation of material inputs such as fertilizers.

The household responsibility system in China provides farmers with a 15-year land lease. As long as local authorities refrain from tampering with these contracts, farmers will have an adequate sense of tenure security and a fairly long planning horizon for many types of farm investments. The land leases are not inheritable, however, and until recently were not transferable among farmers by sublease or by sale, nor could they be mortgaged. The constitution was amended in April 1988 to authorize and legalize the transfer of land use rights. However, implementing policies, regulations, and administrative mechanisms to actually facilitate a land market has only been promulgated since May 1990 and has not yet been initiated. The inability to conduct land transactions has obvious adverse implications for efficiency. The constraint is especially harmful given the high degree of fragmentation and the extremely small size of farms in areas of China. A land market would facilitate consolidation and would enable a reallocation of land to those who have higher productivity.

In the wake of decollectivization and the stunning growth in off-farm employment opportunities in both urban and rural areas, China's "floating" labor force burgeoned, and the traditional destinations of the migratory work force shifted away from the frontiers toward the rapidly growing coastal areas and major metropolitan areas. By some estimates, the size of the migratory work force is about 20 million people. However, in an effort to limit growth of a marginalized urban population characteristic of other developing countries, the government of China has not formally authorized these movements. The result is that the work force is being channeled into seasonal and temporary work, thereby having little real effect on the "mainstream" urban markets and perhaps more efficient factor proportions. Meanwhile, in parts of rural China there are shortages of agricultural labor (again, in the dynamic coastal provinces and peri-urban environs), and local governments are introducing farm mechanization programs because access to agricultural land is constrained by rigid requirements on land leasing and other forms of transfer, in which only local households are authorized under any circumstances to secure rights to farms.

Because the government is not willing to authorize these informal migrations, nor does it have the power to prevent their occurrence, the immediate effect of these policy-induced restraints is the maintenance of fragmented labor markets in both the urban and rural areas, losses in efficiency and potential growth, and--because the floating population is not eligible to obtain urban residency permits--a denial of access to urban services and food ration coupons, causing this population to live in semisqualor and lead a fairly perilous existence. As the migratory work force continues to grow, this issue will become increasingly important.

The major material inputs in Chinese agriculture are essentially not distributed by market mechanisms. Fertilizer marketing in China is centralized. During 1982-88, certain components of the marketing system were liberalized, but China reimposed central control in January 1989. The allocation of fertilizer is linked with crop procurement by the state. About two-thirds of all fertilizer is allocated in exchange for crop procurement. The Agricultural Inputs Corporation (AIC) is responsible for wholesaling about 90 percent of all the fertilizer at national, provincial, and county levels, and the Supply and Marketing Cooperatives are responsible for retailing 85 percent of AIC fertilizer. Fertilizer losses (both physical and chemical) are estimated to be high because existing fertilizer storage and transport facilities are not adequate. Fertilizer supply is allocated (based on productivity, procurement target, and remoteness) by the higher authorities, regardless of local demand. In addition, the mandatory allocation of fertilizer to regions and crops does not take into account crop response to applied fertilizer. As a result, there is potential loss in crop output.

Fertilizer prices in China are administered, generally kept low, sometimes determined arbitrarily, and often not adjusted (especially plan prices) for several years. At present, China follows a dual pricing policy that consists of plan and negotiated prices. Market prices are allowed to fluctuate within maximum price guidelines. The price spread between different prices could be very large. For example, during 1988 urea was sold at ¥520/ton plan prices, ¥700/ton negotiated prices, and ¥1,000/ton market prices. Plan prices are kept uniform country-wide for national fertilizers, province-wide for provincial fertilizers, and county-wide for county fertilizers. Fertilizer marketing costs are fixed and do not reflect the actual economic costs. At present, the provincial and county governments are required to follow the maximum price guidelines for all fertilizers. Nutrient/crop price ratios in China are comparable to many other developing countries. However, plan prices are highly subsidized both directly and indirectly. A conservative estimate of the total financial cost of the fertilizer subsidy in 1988 is about \$1.91 billion. The subsidy generates excess demand among many farmers. Although some free market trading takes place, the "free" markets are fragmented geographically and are not efficient.

The supply of diesel is centrally allocated through provincial authorities. Because diesel serves sectors other than agriculture, there are competing claims on the available supply, but these are resolved essentially by bureaucratic rules and not by the market mechanism. There are three different prices for diesel: (1) the official or subsidized price, (2) the "high" price, and (3) the negotiated price. Diesel supply at subsidized prices is allocated and fixed by the government. Until 1982, diesel was sold at a unified price held constant over several years. The high price was introduced in 1982, primarily for sales to industry. The negotiated price system was introduced in 1986. Diesel supply was linked with contract grain purchase (5 kg diesel/100 kg grain) in 1986. During 1987, the high and negotiated prices were higher than the subsidized price by 60 percent and 120 percent, respectively. Similar problems of misallocation characterize the supply of electricity.

The existing input (fertilizer, diesel, electricity) distribution system has several problems. First, input supply linked with contract grain is difficult and expensive to administer. Second, because there is generally a shortage of fertilizers, diesel, and electricity, the contract input supply system results in leakage and corruption. Consequently, the intended beneficiaries do not fully benefit from the scheme. Third, subsidizing farm inputs results in a large financial subsidy burden. Fourth, market distortions (and many prices) not only confuse the farmer but also result in waste and misallocation of scarce farm inputs. For example, areas with canal irrigation do not really require diesel for irrigation, yet the linkage system allocates it in proportion to contract grain purchase, resulting in waste and economic loss to the nation. With fertilizer, farmers do not always get the type of fertilizer they want nor receive adequate quantities. The distribution systems for fertilizer, diesel, and electricity are inefficient, rigid, and complicated to administer. The complex fertilizer pricing system also needs to be simplified.

Agricultural Investment and Finance

Overview

Structural change on the real side of the agricultural sector has been accompanied by a change in the structure of agricultural financing and a shift in priorities. This became especially pronounced after the reforms were introduced. In 1984, the year of China's largest grain harvest until last year, total state spending on agriculture was actually below what it had been in the first year of the reforms. In recent years, agricultural spending has picked up again, at least in nominal terms, but as a proportion of total state expenditures agriculture's share has declined during the last 10 years. In Chinese agriculture, the prioritization and programming of public expenditures have fallen hostage to the devolution of fiscal responsibility, which militates against substantial support for non-revenue-earning activities. The operation of services expected from these investments probably has also suffered from the excessive fragmentation that continues to typify public sector support for agricultural programs in China. Thus, when one tries to ascertain "revealed" financing priorities, the expenditure picture becomes cloudy because a flow of funds accounting for the agricultural sector--or anything approaching one--is not available. Nonetheless, roughly half of the state's capital construction budget for agriculture in 1987 (#2.1 billion) was allocated to "water conservancy," primarily for irrigation and drainage construction (table 4).

Despite government claims, an examination of central government expenditures reveals that the state has been unable to reallocate a significant portion of state funds to agriculture. This may be related to the difficulties that the state has encountered when trying to reverse the degeneration of expenditure and revenue retention authority, though the state's reluctance to reallocate measurable sums has also undoubtedly been influenced by sensitivity to urban unrest and the continuing priority given to

**Table 4. Natural Calamity and Irrigation
(percent)**

Year	Sown area hit by natural calamity (1)	Share of government investment in: Water control (2)	Agriculture (3)
1953	4.9	5.4	8.6
1954	8.5	2.3	4.2
1955	5.2	4.1	6.2
1956	8.2	4.5	7.7
1957	9.5	5.1	8.3
1958	5.2	7.3	9.8
1959	9.7	7.0	9.4
1960	15.3	8.2	11.6
1961	18.6	8.0	13.3
1962	11.9	11.6	20.2
1963	14.3	12.4	23.0
1964	8.8	10.4	18.6
1965	7.8	8.4	13.9
1966	6.7	n.a.	n.a.
1967	n.a.	n.a.	n.a.
1968	n.a.	n.a.	n.a.
1969	n.a.	n.a.	n.a.
1970	2.3	n.a.	n.a.
1971	5.1	n.a.	n.a.
1972	11.6	n.a.	n.a.
1973	5.1	n.a.	n.a.
1974	4.4	n.a.	n.a.
1975	6.7	6.3	9.3
1976	7.6	7.5	10.8
1977	10.2	7.4	10.8
1978	16.8	6.9	10.5
1979	10.2	6.7	11.0
1980	15.4	4.7	9.2
1981	12.9	3.0	6.5
1982	11.2	3.2	6.0
1983	11.3	3.5	5.9
1984	10.6	2.7	4.9
1985	15.8	1.7	3.3
1986	16.4	1.5	3.0
1987	14.1	1.6	3.1
1988	16.5	1.5	3.0

Note: Area hit by natural calamities refers to sown hectareage reported to be hit by flood, drought, frost, and hail, and to experience 30 percent or more reduction in yield compared with normal yield.

Source: Ministry of Agriculture, Planning Bureau 1989, pp. 354-57; SSB, Fixed Capital Investment Statistics Division 1987b pp. 71-75; SSB 1987, p. 479; SSB 1988, p. 572; SSB 1989, pp. 192, 229, 490.

China's manufacturing and export development programs. The pattern of provincial and local expenditures has reportedly increasingly emphasized the more profitable nonagricultural expenditures. The recent consolidation of off-budget funds under the umbrella of the newly established Agricultural Development Fund (ADF) may help to stimulate official expenditures for agriculture, though the sums involved still are not large (¥2-3 billion annually).

Accompanied by decollectivization--or perhaps because of it--and a substantial devolution of expenditure and fiscal authority to local government, the locus of agricultural financing shifted from budgetary expenditures through the system of finance bureau to the state-owned and specialized banks and to various nonbank financial intermediaries that proliferated in rural China during the 1980s. In this system, the Agricultural Bank of China (ABC) and the ubiquitous Rural Credit Cooperatives (RCCs) predominate but are by no means the only alternative channel. Their lending operations expanded rapidly during the 1980s, especially after 1984 when devolution became complete. Most of the approvals were for short-term advances, however, including large advances to the grain bureau to finance enterprise losses and grain procurement campaigns. Lending for agricultural investment was minimal.

In addition to direct financing through budgetary allocations and the financial system are the funds otherwise diverted to financing agricultural subsidies, urban grain subsidies, agricultural import subsidies, and the operating losses of the grain bureau enterprises. About 85 percent of the comprehensive agricultural subsidy is absorbed by grains and oils ("grains") and, marginally, by cotton. The volume of subsidization is astounding: it is larger than the state's direct expenditure for agriculture in 1988 and about twice the value of annual increments to GVAO since 1984.

During the coming years, both under the near-term regime of macrofinancial stabilization and into the medium term, it may prove difficult for China to finance the state's ambitious grain production goals and food security policies. There are questions of "feasibility" in the fiscal and financial sectors that correspond to the efficacy of targets established in the real sector. Assuming that the grain production targets are at least feasible, the financing of an ambitious program is likely to require a fundamental reordering of intersectorial financing priorities, some reversal of the devolution of revenue and expenditure authority, and a marked reduction in consumer and grain marketing subsidies.

Investment Priorities

Meeting future agricultural growth requirements will depend critically on increases in both cropping intensity and yields on existing cultivated land and on improvements in the quality of production. Expanded investment in agricultural services and infrastructure will be key to realizing these goals. One particular area of concern is the technology generation and transfer nexus.

Food Subsidies

A long-standing policy objective is to maintain self-sufficiency in grain production. Currently the Chinese consume about 400 kg/cap/year of grains, which has become planners' datum. China has been largely successful in achieving self-sufficiency in most grains and animal products, though with some deterioration since the reforms were introduced. In the wake of decollectivization, however, there has been a growing imbalance among the commodity composition of grain production, a rapidly increasing demand for feed grains, and a fairly flat demand for table grains, much of which reportedly is being diverted to supplemental feeding of animals.

Doubling ration grain prices to approximate average procurement prices or tripling ration prices to bring them in line with free market prices would decrease direct grain consumption in urban areas and have a perhaps positive impact on demand for other foods. However, it would be likely to impact badly on the urban poor. In 1988, grain's expenditure share among the poorest 10 percent of registered urban households was about 10 percent, compared with 6 percent for the decile with greatest income, and increasing ration grain prices to free market levels is estimated to decrease these households' real income by more than 20 percent. It will be essential to target reduced levels of grain subsidies to those in real need.

Formal eligibility to receive urban grain rations is restricted to holders of urban residency permits. The actual urban poor, many of whom have been unable to obtain (or are still awaiting) formal certification of residency, comprise a mix of lower-level government officials, retirees, and recent migrants with only indirect access to ration coupons. Unlike the bulk of the urban population, the urban poor remain dependent on grain rations to maintain a decent standard of food consumption. The government will have to return to grain ration system reform, but the design of the reform and the pace of implementation must also consider the possibility of urban backlash. Thus, the more practical questions are (a) whether to compensate all or only currently employed ration recipients, and (b) whether to continue to honor the "overhang" of unused grain ration coupons at prereform prices.

Over the longer term, though, China will have to face the basic question of whether self-sufficiency in grain production is a viable food security strategy. The costs of maintaining the current, highly subsidized system have been noted. If China has also reached its effective grain production frontier, there is the likelihood that further gains in production will entail costly infrastructure investments, expansion onto reclaimed and marginal lands, and the substitution of higher-value agricultural activities with lower-valued grains. China may be well advised to seek a lower degree of grains self-sufficiency, making up the difference through imports.

An Unfinished Agenda

Grain Pricing and Marketing

Perhaps the most important unfinished business in China's agricultural reform milieu concerns the halfway state of current pricing and marketing reform. In a sense, the "easy" steps have been completed, though an uncomfortable mix of central planning and the limited market role continues to hinder performance and efficiency in the all-important grain sector.⁶

Conceptually, the completion of China's agricultural pricing and marketing reforms would seem rather easy: merely eradicate "two-track" pricing and assign full responsibility to market forces for the allocation of China's grain supplies. However, a number of important institutional issues will first have to be addressed, including the near complete monopoly of the state commercial system in the realm of both grain and inputs distribution, the dismal state of much of China's storage and handling infrastructure, continued long-distance transportation constraints, and the ubiquitous urban grain ration system. These areas--in the face of political sensitivities and without a targeting apparatus to provide a safety net for the urban poor--may elude quick reform. All of these militate against the quick-fix approach and require substantial investments to improve the distribution and transportation infrastructure. It is thus probably naive to assume that interregional markets could be created and begin to function efficiently overnight through the simple expedient of price liberalization. Yet China simply cannot afford the costs, financial and economic, that are associated with maintenance of the existing system.

Under these circumstances, reform should be progressive but phased--starting first by raising the administered grain procurement and urban

ration prices for grains and initiating investments to improve China's marketing capacities.

At the same time, to prepare for a more complete liberalization perhaps two or three years from now, the Chinese government should review the role of the grain bureau system and identify institutional, legal, regulatory, and other measures needed to break its effective monopoly in grain distribution and to convert its modus operandi to that normally associated with grain market regulation, i.e., maintaining strategic stockpiles, price stabilization, seasonal procurements and disposals in regions that experience extreme gluts or shortages, and emergency relief and subsidized transfers to chronically poor and remote areas. Meanwhile, enterprises outside the state commercial system should be encouraged to enter the grain trade to gain experience, perhaps initially by renting stores and facilities from the grain bureau's enterprises, and should be allocated space on the state railway system and given access to distribution financing credits through the state banking system (later by participating in divestiture programs and investing in their own marketing capacities).

A necessary component of any attempt to reform pricing and the mechanism for price determination will be a thorough recasting of the urban ration sales system. Since market prices for grain have fallen below the "negotiated" price levels (which constitute the higher of China's two-tiered administrative pricing structure) because of record production in 1989, China could probably seize the moment to raise urban ration prices to reduce the subsidy burden without causing too much of a backlash among urban residents. Simultaneously, however, dates of expiration should be announced (and enforced) on the large overhang of monetized grain ration coupons (by one estimate, these were equivalent in value to 20 million tons of grain in 1988, nearly 20 percent of the total grain sold through the state's commercial system). To do so would cause no extreme hardship to most of the eligible recipients, since their revealed preference in recent years has shifted decidedly away from the direct consumption of table grains, and particularly away from the low-quality grains distributed by the grain bureau. To prepare for further reform of the ration system, a system should be designed that will identify and target only the urban poor; it will replace the existing system once the necessary background studies have been carried out, including a precise identification of the urban poor, the setting of eligibility criteria, plans and procedures to govern the transition, and training programs to help the responsible agencies shift their orientation. During the transition, it will probably be necessary to offer income supplements to all of the existing beneficiaries. However, these should be a onetime-only supplement; otherwise, the subsidy burden will continue to grow, albeit in new clothing, thus defeating the purpose of the reform.

Inputs Pricing and Distribution

The fertilizer distribution subsidies should be phased out (higher grain procurement prices will compensate), the linking of fertilizer distribution with compulsory grain procurement abolished, and China's brief experiment with liberalized fertilizer marketing during the mid-1980s reinstated. A similar effort should be initiated to improve the allocation of fertilizers, though unlike grains, the implementation of this kind of approach must accommodate the continuing shortage of high-analysis fertilizers in China and be implemented even more carefully to prevent a measured erosion of farmers' purchasing power. In addition to reinstating the trial liberalization mentioned above (which mainly involves locally produced, low-analysis fertilizers manufactured in local, small fertilizer factories), the plan prices for the high-analysis centrally managed stocks and imports should be increased and the regional allocation criteria simplified in a manner that would tend to make fertilizers more available to crops having high production and income-earning potential. In this connection, after geographic allocations have been determined, perhaps the higher-analysis but still administered fertilizers could be auctioned off to the farming population,

maybe achieving a "second-best" efficiency and, incidentally, also augmenting revenues to cover current losses in the distribution system.

Comprehensive experimental programs are under way at the regional level, in the north China wheat belt (Xinxiang, Henan) and in the south China rice belt (Yulin City, Guangxi), which are testing some aspects of the above recommendations. Initial results have been encouraging, and key features of these experiments might serve as a model for more comprehensive nationwide reform.

International Trade

These developments are rife with policy implications, both for China and for its trading partners and international competitors. Additional gains could accrue if China shifted from the current annual planning of foreign trade in grains to a longer-term program and made its intentions known. At present, Chinese grain importers and exporters operate largely in the "real" markets on the basis of annual import and export programs. Sometimes its trade volumes are negotiated bilaterally, other times the state trading corporations lift (or place) grains directly and often unexpectedly in foreign markets. This system on the import side allows China to "enjoy" prices more resembling spot prices, occasionally with export enhancement subsidies, than would a less vicarious pattern of import agreements. Shifting to a longer-term approach, however, would also require supporting policy adjustments within China's grain system, including more careful and considered management of its commodity stockpiles (which currently also has a very short-term orientation) and state programming of longer-term financing or the provision of requisite budgetary set-asides for CEROILS and other Chinese FTCs involved in the grain trade. Were it politically convenient for China to do so, these corporations could even sign medium-term contracts or at least issue letters of intent to selected foreign suppliers for core amounts of grain imports and exports (otherwise hedge in international commodity markets), thereby ensuring lower expected prices for grain imports and a smoother--probably higher--progression of f.o.b. prices for its grain exports.

Over the longer term, however, the real gains would come from a decentralization of the management of foreign trade and the internal procurement and marketing of grains. China's parastatals responsible for these operations simply are not efficient or able to respond quickly enough to changing circumstances. Moreover, they have not been able to constrain costs. In 1989, fully one-third of China's enormous grain subsidy was allocated to offset the grain bureau's operating losses, while the equivalent of at least \$350 million was reportedly allocated to finance grain import subsidies. Equally important, the agencies responsible for China's foreign trade in grains neither pass on gains from exporting to Chinese traders and producers nor do they respond readily to market signals and changes in China's internal grain situation. Thus during 1984, which was a peak year in domestic grain production, China imported over 12 million tons of grain, an almost fourfold increase over imports in 1983, the previous year of record grain production. The "stop-and-go" behavior manifested by the agencies responsible for international trade and grain movements within China--largely a response to administrative orders--and the losses resulting from the predominance of state-owned monopolies in China's international and domestic marketings are likely to continue to inhibit the country's ability to exploit its advantage, respond quickly to changing configurations and trading positions in the world's grain markets, and pass on the incentive signals with due alacrity to its farmer producers and grain consumers.

Notes

1. In China both the general public and most economists often regard grain as the entire sector of agriculture. Despite a respectable growth rate for agriculture as a whole in the past five years, agriculture is

often regarded as having stagnated and declined because of the grain situation.

2. This paper draws heavily on Lin, Burcroff, and Feder 1990.

3. The other two policies instituted to facilitate the rapid expansion of heavy industry were low interest rates and overvalued exchange rates.

4. For a detailed chronology of the price changes in 1979 and thereafter, see Sicular 1988b.

5. For a chronology of the policy evolution, see Ash 1988. For a summary of the development from various variants of the responsibility system to the HRS, see Kueh 1984. For a discussion of some new issues related to HRS, see Kojima 1988.

6. For a detailed discussion of developments and policy options in China's grain sector, see World Bank 1990.

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SESSION VI:

**PROSPECTS FOR HIGH-VALUE CROP AND
LIVESTOCK PRODUCTS IN THE 1990S**

**PROSPECTS FOR HIGH-VALUE CROP AND LIVESTOCK PRODUCTS
IN THE 1990S: ADVANCES IN PROCESSING TECHNOLOGY**

Gary W. Williams and Bruce E. Dale

The phenomenal growth of world agricultural markets since the early 1970s is well known. Less well known, perhaps, is that although world markets for grains, oilseeds, and other bulk, low-value farm commodities (LVPs) have grown rapidly, markets for high-value agricultural products (HVPs) have grown even faster (see figure 1 for a definition of high-value products). By 1980, world trade in HVPs surpassed \$120 billion, compared with the \$110 billion trade in LVPs (USDA 1983). World annual HVP trade currently exceeds \$200 billion. HVPs now account for more than half the total value of U.S. agricultural exports. Although developed countries have been the major exporters and importers of high-value products, HVPs account for over 80 percent of the value of developing countries' exports to industrial countries.

Future growth of world HVP production and consumption faces a number of barriers, notably (a) protectionist policies of importing countries and competing export suppliers that restrict trade in value-added products relative to that of raw commodities; (b) the lack of effective demand (i.e., buying power) in less developed countries; and (c) the paucity of international food science research and the processing skills and technology required to develop higher-value processed food products with the physical characteristics most desired by consumers in diverse countries that also conform to traditional food preparation and consumption practices (Williams 1989).

The optimism regarding the possibility of reducing the first of those barriers has diminished considerably with the breakdown in the Multilateral Trade Negotiations last year. The prospects for world trade barrier reduction are currently dim. The effective demand barrier has been steadily but slowly reduced over time as development has proceeded worldwide. Countries such as Japan, South Korea, and Taiwan are prime examples not only of success in economic development but also of the global impact that such development can have on the pattern and composition of world agricultural production and trade. The processing technology and food science research barrier, however, may be the most difficult to overcome because of the lack of research funding and the necessary technical and scientific skills, particularly in developing countries.

This paper explores recent advances in processing technology that could provide the basis for expanded world markets for new, higher-value food, feeds, and industrial products from agricultural materials. Biologically based processing technologies are highlighted because of the relatively greater perceived impact such technologies are likely to have on world agricultural markets over the next decade. The policy implications of these developments and the need to integrate policy goals with process technology development and implementation are also emphasized.

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Figure 1. Classification of High-Value Agricultural Products

Semiprocessed products	
Fresh, chilled frozen meat	Tea
Wheat flour	Animal feeds
Refined sugar	Oilseed cake and meal
Coffee	Animal oils and fats
Cocoa	Vegetable oils
Highly processed products	
Prepared/preserved meats	Dried fruit
Milk	Preserved/prepared fruit
Butter	Preserved/prepared vegetables
Cheese	Nonchocolate sugar preparations
Cereal preparations	Chocolate
Beverages	Misc. food preparation
Spices	Cigarettes
Traditional high-value products	
Eggs	
Fresh fruit and nuts	
Fresh vegetables	
Low-value products	
All other products	

Prospects for World High-Value Agricultural Product Markets

The global production and consumption of high-value agricultural products are primarily a developed country phenomenon. The major traders of high-value products, therefore, are also developed countries such as the United States, the EC-12, and Japan. For example, HVPs accounted for 52 percent of the value of U.S. agricultural exports in 1987, nearly half of which went to the EC-12 and Japan. Traditional and semiprocessed products account for most U.S. HVP exports, but highly processed, consumer-ready products have increased rapidly since the early 1970s. The leading U.S. traditional HVP exports include cotton, hides and skins, and fresh fruits and nuts. The most important semiprocessed U.S. HVP exports are fresh and frozen meat and oilseed meal. Highly processed U.S. HVP exports include cigarettes and various food preparations.

A recent phenomenon in world HVP markets has been the emergence of developing countries as major exporters to developed countries. Over the period 1970-87, the value of developing country HVP exports to developed countries experienced nearly a fivefold increase, reaching \$37 billion in 1987. Although traditional HVP products constitute the bulk of developing country exports to developed countries, more highly processed product exports have experienced a more rapid growth. The leading traditional HVP developing country exports to developed countries include coffee, fresh fruits and nuts, and cocoa (table 1). Their most important semiprocessed exports include shellfish, oilseed meal, and vegetable oils. Highly processed HVP exports from developing to developed countries consist mainly of preserved fruit, most of which is frozen orange juice concentrate. Latin American and African countries are the main developing country exporters of traditional HVPs such as fresh fruits and vegetables, nuts, sugar, and cotton (figure 2). In

**Table 1. Developing Country Exports to Industrial Countries
(millions of dollars)**

Exports	1970	1975	1979	1983	1987
Total agriculture ^a	10,786	20,148	38,892	34,996	44,715
Total HVPs	8,169	15,688	31,018	28,535	37,180
Unprocessed	5,583	10,807	18,306	15,987	19,535
Semiprocessed	1,895	3,794	9,625	9,194	12,195
Highly processed	691	1,087	3,088	3,354	5,450

Note: Industrial countries include the United States, EC-12, Japan, and Canada.

a. Total agricultural exports, including fish and cigarettes.

Source: United Nations.

Figure 2. HVP Exporters

Traditional		
Cameroon	El Salvador	Mauritius
Chile	Ghana	Mexico
Colombia	Guatemala	Nigeria
Costa Rica	Honduras	Pakistan
Côte d'Ivoire	India	Turkey
Dominican Rep.	Indonesia	Uganda
Ecuador	Kenya	Zimbabwe
Egypt	Madagascar	
Nontraditional		
Algeria	Malaysia	Thailand
Argentina	Morocco	Tunisia
Brazil	Philippines	Uruguay
China	Singapore	Venezuela

contrast, Asian and South American countries dominate the semi- and highly processed exports of developing countries.

Despite their success in exporting higher-value agricultural products, developing countries import only a relatively small share of what is exported. Nevertheless, future growth in world HVP exports may well depend on growth in demand for HVP products in developing countries for several reasons. First, the future prosperity of developed country agriculture is closely tied to growth in global export demand, which is largely dependent on the rate of growth in developing countries. The strength of the export demand facing developed countries is determined by a number of forces in foreign countries, including (a) population size and growth, (b) income level and growth, (c) growth of domestic supply, (d) agricultural policies, and (e) foreign exchange availability. A quick survey of countries suggests that without growth in less developed countries (LDCs), the prospects for strong growth in developed country export demand are limited. In developed countries, population growth is low; per capita income levels are high, but food demand is relatively unresponsive to income changes; domestic food supplies are growing; and import policies are highly restrictive. Middle-income countries such as Taiwan and South Korea have experienced rapid growth in recent years, but those markets are quite limited in size. Emerging democracies in Eastern Europe and the People's Republic of China have great potential, but have been quite erratic in their import behavior. There are no particular obvious trends to suggest that food imports by many of these countries will grow significantly and

become more consistent in the near future. Although the continuing democratization of Eastern Europe may yet lead to an increase in demand for developed country exports, any significant increase is neither imminent nor certain. In developing countries, however, population is growing rapidly; incomes are low, but food demand is highly income-elastic; domestic food supplies are not growing as rapidly; and imports of higher-value products, in particular, are much less restricted. Income growth and improvements in foreign exchange in these countries are likely to be the best hope for future growth in foreign demand for developed country agricultural and food products.

Second, economic growth is normally accompanied by a shift in consumer demand toward higher-value and -quality products. In general, the income elasticity of demand for higher-value food products tends to be higher than for lower-value products. Consequently, as development proceeds and per capita incomes rise in many currently developing countries, there will be a relatively larger increase in demand for commodities such as meat and meat products, fruits, and processed grain products than for foodgrains such as rice and wheat and traditional food products.

Last, as a corollary to the previous point, growth and development tend to shift the composition of world trade toward higher-value products. The historical pattern of change in the composition of world agricultural trade from food and industrial products in the early 1900s to feed and higher-value products more recently is closely related to the pace of development in food-importing countries, including Europe, Japan, the Soviet Union, Taiwan, and South Korea. Growth in developing countries will continue to change the composition of world agricultural trade toward higher-value products.

Although food products are the principal HVPs derived from agricultural raw materials, nonagricultural, industrial products (fuels, chemicals, polymers, fibers) are a growing and increasingly important source of demand for the output of world agriculture. For instance, approximately 800 million gal/year of fuel ethanol are currently produced from the U.S. corn (maize) crop. This represents about 5 percent of the corn crop but far less than 1 percent of total U.S. gasoline consumption (about 110 billion gal/year). In 1990, U.S. production of major organic chemicals, plastics, and synthetic fibers exceeded 160 billion pounds (Chemical and Engineering News 1990). Many of those industrial materials can be made from agricultural raw materials or interconverted as demand changes, particularly by taking advantage of the inherent flexibility of chemical and biochemical processing technology. In 1980, total production of oxychemicals, those chemicals most easily produced from agricultural raw materials, had a total market value in excess of \$14 billion (table 2). Environmental concerns, the cost (and uncertainty) of oil imports, and the need for rural development increase the pressure to develop industrial products from renewable plant materials.

Advances in Processing Technology

It is impossible to cover in one article the entire range of advances in processing technology, much less to accurately predict which technologies are likely to have the greatest impact. There are, however, a number of important recent advances in processing technology that hold promise for new and additional uses of animal and plant materials. These technologies can be classified as either biologically or nonbiologically based. A few of the more recent nonbiologically based technologies are reviewed briefly. These include food irradiation as a means of preserving foods; advances in oilseeds processing research, particularly the deallergenation of castor seed; and technology developed to utilize kenaf, a new fiber crop with multiple actual and potential uses. Biologically based technologies discussed include starch- and cellulose-based processes to produce fuels and chemicals (including polymers) within integrated biomass processing schemes. A new process that unlocks the carbohydrates available in cellulosic materials is described and discussed.

Table 2. Oxychemicals

	1980 U.S. value (\$ millions)
Ethanol	
Ethylene	6,800
Butadiene	1,300
Octane enhancer	600
Industrial	400
Total ethanols	9,100
Ethylene Glycol	1,260
Adipic acid	1,030
Acetic acid	620
Isopropanol	500
Acetone	460
Acrylic acid	360
Glycerol	250
1,4-Butanediol	240
Propylene Glycol	220
Methylethyl Ketone	210
n-Butanol	200
Citric acid	190
Sorbitol	90
Propionic acid	35
Fumaric acid	25
 Total oxychemicals	 14,790

Nonbiologically Based Processing Technologies

The traditional means of altering the form, size, composition, appearance, texture, or other attributes of raw agricultural products to produce new products of potentially higher value include a broad range of physical and chemical technologies. Such processing technologies include, for example, various methods to measure and alter the fat, cholesterol, sodium, calcium, or other mineral levels in animal products to meet growing consumer demand for a more healthy, nutritious diet. Other common nonbiologically based processing technologies include various extrusion, extraction, fractionation, and similar processes. One process receiving much attention in recent years is the use of high-energy electromagnetic disturbances as a means of preserving foods and extending their shelf life. Otherwise known as irradiation, the process uses machine-generated radiation, or radioactive isotopes as is more common with food, to kill or to render sterile various pathogenic organisms, insects, and/or spoilage bacteria. Among its current uses are the treatment of spices and dry condiments in the United States; meats, fruits, and vegetables in China; potatoes in Japan; and grains in the Soviet Union (Hayes and Molins 1987). Although irradiation technology was developed nearly 50 years ago, extensive use of the process has not occurred because of continuing questions about the possible health risks. The preponderance of scientific evidence suggests, however, that irradiation causes no ill effects.

Another noteworthy innovation in food processing is the development of a process to detoxify or deallergenate castor seed meal. Castor seed is a productive and widely grown oilseed with a high-quality oil that, in addition to its food/feed uses, has many actual and potential uses in the chemical industry. Unfortunately, the value of the residual meal after oil extraction is limited because of the toxins (ricin and ricinine) and the allergens that it contains. The detoxification/deallergenation process has been demonstrated at the pilot plant level on commercially available expellers

and extruders. Commercial testing is now under way (Rhee and Kim 1990). The development of this process and its commercial application will permit an additional oilseed meal to enter the food/feed market and will improve the economics of castor oil use for industrial products.

Over the past 40 years, the U.S. Department of Agriculture and several private organizations have worked to industrialize a new fiber crop, kenaf (Kugler 1988). The technology to process kenaf into newsprint has recently been developed. Plans to construct the world's first kenaf-based newsprint mill in south Texas by 1991 were recently announced. Kenaf is a fast-growing annual plant, native to Sudan and East Africa, which matures in about five months. Kenaf yields three to five times as much dry biomass per acre annually as do trees at about half the cost. Kenaf-derived newsprint is brighter and stronger than that made from trees and uses less ink, less pulping energy, and fewer chemicals. Successful worldwide commercialization of the kenaf newsprint technology would make kenaf a highly viable alternative fiber crop, particularly for the tropical and subtropical developing world. This new technology could have major impact on agricultural production and incomes in developing countries and could significantly reduce the pressure on world forestry resources undergoing rapid depletion.

Biologically Based Processing Technologies

Biological processing (bioprocessing) refers to the use of cells or cellular components to add value to raw input materials. Bioprocessing technology is an ancient practice. The Egyptians used the process over 5,000 years ago to produce beer and wine. In recent years, advances in the biological sciences, coupled with various societal concerns, have propelled bioprocessing technology development. Bioprocessing is inherently flexible in both the raw materials used and in the products generated. At the same time, bioprocessing tends to conserve nonrenewable resources and is less likely than conventional chemical processing methods to cause environmental damage. The relevance of this technology is that, in general, agriculturally derived material are utilized as feedstocks to produce high-value foods (beer, wine), fuels (ethanol, methane), chemicals (acetic acid, butanol, acetone), and polymer feedstocks (adipic acid, hydroxybutyric acid), all through fermentation of sugars derived from sucrose, starch, or cellulose. Because sucrose-based conversion technologies are rather standard and few advances have been made in recent years, this section focuses on starch-based conversion and cellulose-based conversion technologies.

Starch-Based Conversion Technologies

The corn processing industry has developed to an advanced degree of sophistication and capability in the past 50 years. Although there are no exciting recent technological developments to report, the corn wet milling industry provides a good conceptual model of what a well-developed crop processing industry should look like and provides a convenient introduction to cellulose-based conversion technologies discussed in the next section.

The approximate composition of corn grain is shown in table 3. The dominant component is starch, hence the reference to "starch-based" conversion technologies. The dominant corn processing technology is the wet milling process. The process functions by separating or "refining" the grain into its major components: oil, starch, and protein. Effective separation and subsequent upgrading to higher-value uses of each of the components of the heterogeneous agricultural raw material is essential to developing a viable industry based on processing that raw material. For example, corn starch can be converted into a wide variety of food and feed ingredients as well as industrial chemicals:

sweeteners	explosives
ethanol	soaps
adhesives	paper
textiles	insecticides
paints	polymer foams

The recent negotiations between one corn processor, Archer Daniels Midland, and Pfizer Chemical to acquire Pfizer's citric acid production capability (the citric acid process is based on fermentation of the sugars derived from corn starch) are an example of the continuing vertical integration of the corn refining industry. Approximately 200 million metric tons (mt) of corn grain are produced in the United States every year. Over half is fed to animals; 30 percent is exported; and the remainder is further processed into sweeteners, starch, flour, cereal, animal feeds, vegetable oils, alcohol fuels, and hundreds of other industrial products (Corn Refiners Association 1989). Any new crop processing industry can learn much from the corn refining industry. Perhaps the key lesson is that multiple valuable products must be generated for such industries to be economically viable. Industries that focus excessively on one or only a few products are highly vulnerable to economic and technological changes.

Table 3. Composition of Corn Grain

<u>Component</u>	<u>Average (%)</u>
Starch	61.0
Protein	9.0
Pentosans	5.3
Oil	3.8
Fiber	2.0
Sugars	1.6
Ash	1.3
Moisture	16.0

Cellulose-Based Conversion Technologies

Cellulose is a sister molecule to starch. The individual glucose sugar units that make up starch are easily accessible. Consequently, starch is highly digestible by people, animals, and microbes. In cellulose, however, the glucose sugar units are very difficult to access, so that cellulose is nearly indigestible by both people and animals. Why is this so important?

Each year about 3 billion mt of food and feed crops are produced worldwide, consisting largely of starches, sugars, protein, fats, and oils. In contrast, approximately 200 billion mt of cellulose-containing biomass (referred to collectively as fiber) is produced annually by photosynthesis--approximately 100 times the world's grain "income" (table 4). This represents a per capita fiber "income" of about 35 mt/year for every person on the planet. Unfortunately, this vast resource of fiber contributes little to the world's rapidly growing food, feed, and fuel/chemical needs, primarily because of the physical and chemical characteristics of biomass fiber and the cellulose within it. Another perspective on the importance of fiber and fiber utilization is that the energy equivalent of the world's green plant fiber income is about 600 billion barrels of oil per year, much more than 20 times the level of oil currently consumed in the world and more than 10 times the total world energy demand from all sources (table 5). If the sugar energy contained in cellulosic plant material could be economically accessed, global fuel use could be better integrated with the global carbon cycle to produce oxygenated fuels, often referred to as "grassoline." Until recently, the

**Table 4. Perspectives on Biomass
(millions of tons)**

	<u>Annual world production</u>
Sugar (cane and beet)	120
Starch	1,100
Cellulose	100,000

**Table 5. World Energy Consumption, 1986
(billion barrels of oil equivalent)**

<u>Region</u>	<u>Oil consumption</u>	<u>All energy sources</u>
North America	6.3	15.7
Latin America	1.7	3.0
Western Europe	4.5	9.8
U.S.S.R.	3.4	10.9
Australia	3.2	6.7
Other	3.2	12.4
Total	22.3	58.5

physical/chemical barriers to accessing this sugar energy, however, prevented such a process from achieving technological and economic viability.

The recently developed Ammonia Fiber Explosion (AFEX) process overcomes the physical/chemical barriers to fiber utilization (Dale and Moreira 1982). The process is currently undergoing scaleup and commercial testing. Nonetheless, the simplicity and mild conditions of the AFEX process should help minimize its costs. After AFEX treatment, sugar yields from bagasse, a fibrous residue from sugar cane processing, are increased sevenfold. These sugars can be fermented into ethanol or a wide variety of other fuels and chemicals, fed to animals, or perhaps even purified for direct human consumption. If 1 mt of bagasse costing \$20 is converted to a highly digestible ruminant animal feed, the estimated return on investment is 60 percent. The same metric ton of bagasse can also be AFEX-treated and further processed to produce fuel ethanol and lignin, a plant material with many potential uses as a fuel, chemical, polymer, or adhesive. The estimated return on investment for this process is 40 percent.

The AFEX process provides a good example of how crop processing can help buffer the agricultural sector from excessive dependence on a few commodities. For instance, Brazil has made an enormous investment in producing ethanol fuel from sugarcane. This was perhaps acceptable in times of low world sugar prices. In recent years, however, world sugar prices have risen, and sugar producers have quite naturally sold into the more profitable food market. Consequently, Brazil has had to import corn-derived ethanol from the United States to fuel its ethanol-converted vehicles. Cane sugar to ethanol will probably never be an economical process for the longer term because it converts food into fuel. Over time, food will always be relatively more valuable than fuel. In addition, there are moral/ethical issues involved in converting food to fuel. Note that both corn grain production and corn ethanol production are heavily subsidized in the United States. Without these subsidies, it is likely that ethanol-blend fuel would cost in excess of \$3.00/gal.

When the AFEX process is introduced into the sugarcane "refining" equation, an entirely different economic result ensues. Sucrose can continue to be sold either as a human food or converted to alcohol, depending on sugar market prices. The bagasse can be AFEX-treated and converted to alcohol and lignin or fed directly to ruminant animals, depending on current economic

conditions. By diversifying products and switching between markets, the agricultural sector can better cope with economic cycles and changes in demand. In addition, more products can be generated for local markets, thereby strengthening the entire economic infrastructure of the crop-producing country.

Coproducing food and feed proteins along with industrial materials may be a promising product diversification scheme for many countries. For example, grasses such as coastal bermuda grass produce up to 25 percent protein in addition to the sugars found in their cellulose fiber (50 to 60 percent of plant dry matter). When these sugars are removed through a process such as fermentation to produce fuels or chemicals, a high protein residue is left behind that is suitable for feeding to ruminant and nonruminant animals and that, with further processing, might also be fed directly to humans (Dale 1983). Many other processing options exist for coproducing protein and fuels or chemicals. A long research and development history is available on this plant protein (called "leaf protein"). It is an excellent, highly nutritional protein. Leaf protein extraction processes have generally failed in commercial practice, however, probably because inadequate attention has been paid to developing integrated processes that separate and add value to the remaining components of the leafy biomass, including the fiber or cellulosic portion (the "refining" concept again), as shown for corn processing. The AFEX process may sufficiently increase the value of the fiber portion to make these leaf protein processes economically viable.

Policy Implications and Integration

Chief among worldwide objectives of agricultural policies have been farm income support and rural growth and development. In general, such policies have focused on fostering growth in the production and marketing of bulk agricultural products. Growth in productive activity in a country relating to bulk agricultural products provides direct benefits to the farm sector in the form of higher prices and increased employment, not only in on-farm activities but also in the input and marketing sectors. Growth in the production and marketing of value-added agricultural products, though, expands the economic impact of the farm sector beyond that of bulk commodities by employing additional resources in a variety of productive activities beyond the farm gate. Unfortunately, however, although the processing and distribution systems (measured by value added) supporting and supported by production agriculture have become the dominant economic components of the food and agriculture systems of most developed countries, most public research dollars support production agriculture. In the United States, for example, 70 percent of the public research dollar goes for production research, whereas only 30 percent of the consumer's food dollar goes to the producer. Conversely, 30 percent of the public research dollar is used for research in food processing, marketing, and nutrition, and 70 percent of the consumer's food dollar is spent on services after the product leaves the farm gate. A major portion of the research to develop new, higher-value products may well be the role and responsibility of the private sector. Nevertheless, there is likely to be a tremendous return in terms of rural sector development and growth from public incentives and investments in research to develop new technologies to convert low-value raw agricultural products into higher-value industrial and consumer goods. This is particularly true when the returns from such investments may be difficult for private sector firms to capture.

The use of renewable plant materials to meet an increasing portion of global needs for industrial materials, in addition to the role they already play in meeting food and feed needs, is growing in importance. Careful planning and wise use of new and available technology, however, will be required to avoid putting food/feed uses of plant materials (and the resources to produce those materials) in competition with industrial uses of plant materials (and their production inputs). One approach consistent with a clear conscience is to coproduce, for instance, protein food and ethanol fuel from grasses that are not now human foods and that, in fact, are relatively poor

animal feeds for many species. Effective utilization of the huge potential resource of cellulosic fiber using the AFEX and other cellulose pretreatment technologies may make this possible. Implications of AFEX technology include:

- economically viable use of renewable income;
- increased human food resources;
- rural development options;
- reduced trash volume;
- economic opportunities for developing countries;
- ecologically superior food/fuel production;
- ecological diversity of raw materials;
- process flexibility/product diversification (decreased risk).

Success in developing integrated technological processes for coproducing foods/feeds and fuels/chemicals from renewable cellulosic biomass could have a number of important potential policy and environmental implications:

- Only biologically derived fuels do not add to net atmospheric carbon dioxide levels and the associated greenhouse effect because the carbon dioxide is recycled through plant biomass to generate new fuel. In contrast, fossil fuels pump carbon from below ground to above ground. Other oxychemicals (see table 2) produced from plant materials have the same advantage of not contributing to net new atmospheric carbon dioxide and will, in general, be more biodegradable than petroleum-derived chemicals. Ethanol combustion also reduces emissions of other pollutants, including those contributing to acid rain;
- New technologies under development, such as the AFEX process, will allow a wider variety of cellulosic materials to be used as feedstocks for crop conversion to fuels and chemicals, increasing the opportunities for agricultural production diversity, permitting greater use of preferred regional and local plant species in the agricultural production systems of developing countries, and minimizing herbicide/pesticide use through reduced dependence on monoculture crop systems;
- Perennial grasses could emerge as a viable economic alternative to crop production through the development of technologies that utilize such grasses as feedstocks for crop conversion. The consequences could be wide-ranging, including a reduction in both soil erosion and fertilizer runoff (and the resultant pollution), an improvement in soil quality, alleviation of the effects of droughts on agricultural output and incomes, an increase in total and per acre protein production worldwide, and an enhancement of overall agricultural productivity since the entire plant can be used, not just the grain;
- Human food resources could increase, both directly from an increase in digestible materials (carbohydrates and proteins) through the application of various new technological processes and indirectly from a substitution of cellulose-derived sugars for grains and other foods now fed to animals or used to produce industrial materials;
- New technologies may also allow waste cellulosic materials (municipal solid wastes, lawn and leaf residues, sewage sludge and crop processing residues, hulls, bagasse, etc.) to be processed into useful materials while minimizing the volumes of wastes with which municipalities and other organizations must cope;

- With the additional demand for new and traditional crops as crop conversion feedstock that the new technologies could facilitate, the need and cost of public support of agriculture around the world could be significantly decreased. At the same time, developed and developing countries dependent on foreign sources of food and industrial materials such as fuels and chemicals could reduce their import costs, improve their trade balances, and earn foreign exchange from exporting excess industrial byproducts of crop conversion processes. Increased global diversification of fuel and food supplies could also help encourage world economic and political stability.

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AGROPROCESSING FOR SMALLHOLDERS

Kenneth G. Swanberg

How can smallholders become involved in agroprocessing? This paper explores development of a model to identify what crops smallholders can produce so that agroprocessing becomes feasible. The model will have six elements: technology choice, environmental adaptation, comparative advantage, vertical integration, the learning curve for manufacturing, and backward linkages. The paper will concentrate on Africa, which has lagged behind Asia and Latin America in the development process. Africa is now poised for rapid development but cannot follow blindly the development paths of the other two continents. Norman Borlaug and Vernon Ruttan led the way in the agricultural development process in Latin American and Asia. Borlaug developed the high-yielding varieties in Mexico that were introduced into the Punjab, and Ruttan chronicled the process by developing the best-known model for agricultural growth, the induced technological change model, or induced innovation model. However, neither the high-yielding varieties nor the induced technological change process has met with much success in Africa. Moreover, to a certain extent the high-yielding varieties approach failed in Asia and Latin America as well, a result of hostile environments, that is, excessively dry land (over 50 percent of India) or land populated by poor farmers (over 50 percent of Latin America). Given these limitations, what can work for smallholders? Can agroprocessing still be viable? First, an analysis of the choice of appropriate technologies is given.

Technology Choice

The induced innovation model of Hayami-Ruttan shows which factors dictate technology choice and how this model runs into some strange twists when applied to Africa. The basic conditions that led to the technology jump in Asia and Latin America do not exist in Africa, and therefore the types of technologies that led to the green revolution cannot be transferred to Africa without modification. The Hayami-Ruttan induced innovation model is based on a view of dynamic factor substitutions driven by market forces. Under certain conditions, innovation rapidly occurs. When these conditions are absent, innovation lags, stagnates, or declines. The basic premise of this model is drawn from the creators' analysis of agricultural growth in the United States and Japan over the last 100 years.

The model holds that technological change comes about through research on factors of production that lower per unit costs, or conversely, increase yields per unit of input. The key to the particular research strategy chosen in terms of the input selected, and the size and nature of the research effort, is determined by one input's ability to substitute for another input whose availability appears to be reaching its limit. If an input experiences an inelastic supply curve, that is, access to more of those resources does not increase when prices rise, then a search is made for a substitute through the research (experimentation and trial and error) process. The degree of effort and the organizational structure pursued in this process are determined by the nature of product demand facing the farmers. If there is broadly based demand with increasing prices, that is, rising urban incomes, this research will be directed toward staple food crops managed by public sector institutions. If the demand is for specialized export crops, research will be financed and conducted by private or semiprivate organizations. In

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any case, the value of the ratio of the price of the input being substituted for the scarce resource and the product's price in the market will determine the size of the research effort and its longevity or sustainability.

Given this model, what is the situation in Africa? First, domestic demand for agricultural commodities is low because of small urban populations and low purchasing power, with food prices often kept artificially low and controlled to garner the political favors of the urban elite. Moreover, factor endowments in Africa do not mesh with either the Asian or Latin American situations. In Asia, where land is scarce and labor abundant, new seed varieties were designed to be particularly responsive to cheap fertilizers, i.e., the land-saving technologies approach. An abundant, cheap resource replaced an inelastically scarce resource. In Latin America, machines were developed to replace labor that was drawn to industry on expansive lands. But in Africa, especially since 1973, inputs have been expensive, labor scarce, and land expansive (though infertile). There are no "cheap" factors to replace those of inelastic supply. Thus, the key ratio px/py is not small enough to induce adoption of the new, high-yielding technologies. The py in the ratio is extremely low, and the px in the ratio is relatively high, perhaps even forcing the ratio to be greater than one. Certainly, this situation cannot lead to economic benefits or profits that would induce investment in the development of high-yielding varieties for food crops, which generally demand high levels of purchased inputs. Moreover, if one is going to consume one's own product, there is little capacity to purchase inputs for its production--the low-productivity trap. Food commodities for internal consumption are not viable alternatives for agricultural growth under these conditions. The technology shift seen in Asia is constrained in Africa.

Environmental Adaptation

The factor endowments identified above--land, labor, and capital--are even more bizarre in Africa than one might realize at first glance. Drought conditions are increasing as more land comes under production, and overgrazing continues and expands. Humidity is reduced as ground cover vanishes, and dry spells last longer and become more frequent. Soils become more fragile, and drought recovery rates slow down. Innovative technologies designed for drought conditions are much different from those developed in Asia or Latin America under favorable moisture regimes. Breeding for resistance and tolerance is different from breeding for high yields. The latter assumes that a host of supporting conditions exist; the former recognizes the extent of scarcity that persists. A wholesale transfer of technologies from these other regions is fruitless. Good Cadillac seeds fall on barren land (compare the sleek car that needs high-octane ethyl trying to run on gasohol or home heating fuel).

Under the dryland regimes of Africa, which experience great variability in rainfall by season and year, production risks are very high. If inputs are applied and then rainfall falls short, the losses are tremendous and devastating. What can be done, then, considering Borlaug's statement that yields cannot be adequate if artificial nutrients are not applied?

There are some technologies that are productive and sustainable under those conditions. The first involves water harvesting. In Kenya, this can be done with simple terraces, as found in Machakos; Kitui ridges, found in Kitui; the Yatta Furrow, also in Machakos; and area canals to divert field runoff into downstream fields, in Turkana; or in Botswana with field channels. Another technique of water control involves measuring early rain and the onset of rainfall to make predictions of the season's precipitation, a model that Ian Stewart has perfected in many countries. Drip irrigation by bucket can also be done. Last, an attempt can be made to grow and develop through breeding drought-resistant, drought-tolerant, or drought-avoiding crops, i.e., crops that require much less moisture for full maturity. Farmers all know this, and that is why there are corn and beans in Zone III, cotton and

pigeonpeas in Zone IV, and sunflower and cowpeas in Zone V. (Zones refer to Kenya's agroclimatic zone classifications.)

In addition to moisture management, these technologies need nutrients. This can be achieved through crop residues, mulches, green manure, etc., as well as conscious intercropping and relay cropping with legumes, which leave nitrogen in the soil after harvest or, if relayed appropriately, can contribute nutrients during production. In this same context, alley cropping with Leucaena or Gliricidia can produce all the nitrogen required for these crops, and some agroforestry systems using fallout from Acacia can also be introduced.

There are technologies that exist that can perform adequately, even well, under these stressed conditions. However, the now famous farming systems approach that was developed to adapt the input levels of the high-yielding technologies to local farmers' resource limitations in Asia and Latin America failed to promote the right technologies and commodities in Africa and as a result, never became a dynamic force for change and growth as it had in those other arenas. What was needed and never really materialized was a clear understanding of how these high-yielding technologies fared under stress. Although Donald Duvick showed that newer maize hybrids always outperform the older ones, even under different levels of stress, it was not shown how new seeds fared compared with old or traditional varieties under severe stress. There is some information, from Zandstra at IRRI, Swanberg's work in Caqueza and Kenya, and CIMMYT's experience in Puebla, that the new seeds failed to yield as well as the traditional varieties under stress--low moisture, low fertilizer, pests, and weeds. If these conditions prevail a few years out of 10, the farmers will choose the local variety for insurance over the introduced new seeds. Obviously, this complicates the ability to place the new technologies into the African drylands environment. The Sasakawa-Global 2000 "success" came in irrigated Sudanese areas and high-moisture areas of Ghana, not the stressed, rainfed areas of agroecological Zone IV. Moreover, the farming systems approach as it was employed in Africa failed to take an in-depth look at the markets, both regional and international, and what comparative advantages could be garnered by commodities from the arid and semiarid lands (ASALs) in these markets.

The identification of commodities that have adequate yield levels when low-cost input technologies are used, and which face relatively elastic international demand schedules, becomes the critical issue: the p_x/p_y ratio has to be reduced by creating high values for p_y -elastic international demand markets and low values for p_x -through drip irrigation, terraces, and water harvesting; legume rotations for nitrogen; crop rotations for pest management; etc. By choosing the right crop mix and input combinations and developing direct linkages to international markets, a comparative advantage can emerge to allow induced change to occur and the Hayami-Ruttan induced innovation model to kick into gear.

Comparative Advantage

Despite the constraints of these technology requirements, are there crop opportunities with clear comparative advantages? At first glance the choices are severely limited. However, further study reveals that even traditional crops whose markets are controlled by international agreements or country-specific quotas have relatively elastic markets when the basic product is transformed into a semiprocessed or manufactured good. Frequently, when economists study a commodity system, macrodata on exports and imports are analyzed with published border prices for the basic commodity, averaging over all varieties, qualities, and years. The demand for all of these dryland commodities is extremely strong when their processed-form markets are identified. (These products and markets will be discussed later). However, the full realization of the inherent comparative advantage for these commodities does not materialize without the concomitant development of a set of conditions that facilitates their transformation in form, time, and place.

Vertical Integration

In the induced innovation model, technologies were developed to enhance the substitution of cheap, abundant inputs for the one input facing inelastic supply, thus generating spurts in productivity. But this was done in a context of a host of institutional supports wherever these conditions have led to technology jumps. What goes unnoticed in these situations is that there are a number of supporting factors or inputs that are required for the effectiveness of these innovations to be realized. In Asia, new seeds were bred that were often hybrids, which had to be multiplied each year and delivered to farmers, and were purchased for cash or on credit. Fertilizers, relatively cheap though certainly not costless, had to be imported, repackaged, distributed to farmers, and purchased for cash or on credit. Transportation companies were involved in the distribution on accessible roads, and gasoline was not exorbitantly priced. Farm machinery was generally available, and credit was present and attainable. Information on the source of inputs, their prices, expectations on output prices, knowledge of what technologies to use, etc., was made available to "literate" farmers (i.e., those with common customs and language and in possession of a radio). Markets for output were accessible, and buyers were plentiful. All of these factors were taken for granted and created an environment that ensured the success of the green revolution in Asia and parts of Latin America. Rice and wheat grew in the absence of moisture-stress, either because of irrigation or heavy, adequate rainfall. Where moisture was lacking, the revolution failed to materialize. Sometimes, the strength and value of the new technologies stimulated improvements in this institutional setting.

Unfortunately, this setting is inadequate or completely absent in Africa. Any attempt to introduce the green revolution in Africa must simultaneously activate these institutions. Recall Norman Borlaug's comments on the plea for credit in the Global 2000 project in Ghana. The px/py ratio was high, so these institutional supports would not be forthcoming and induced from the technologies alone as the Hayami-Ruttan model recorded in Asia. It is in this context that agroprocessing plays a major role.

Agroprocessing takes on many forms. Packaging a fresh product in cartons to avoid crushing during marketing is an agroprocessing activity. Canning vegetables, making fruit juice, tanning leather, ginning cotton, fermenting cocoa--all of these activities are agroprocessing initiatives. Each process transforms the raw product to make it more attractive, gain shelf life, and bring a higher per unit price. A processing activity can also reduce input price by pooling in bulk for shipment, including various qualities in the processing, or reducing the cost for inputs. An agroprocessing firm often provides the input at reduced cost, or at no cost, and collects the cost after transformation. Agroprocessing firms are heavily involved in financing the production, processing, marketing, inventory, and technological assistance. The critical issue that agroprocessing activities address, however, is marketing. By determining what form the product must take to penetrate all markets, the agroprocessing element becomes the critical missing factor in determining the success or failure of a commodity's contribution to economic growth. Without a market and transaction, agricultural production does not contribute to economic growth and poverty alleviation. When agricultural production is simply for autoconsumption, then inputs must be subsidized and/or family needs provided by welfare. The system will not support itself.

This entire set of institutional supports must be developed in tandem with technology introduction in Africa and across the board for productivity changes to iterate the metaproduction function and thereby contribute to economic growth. Several new programs are now emerging that attempt to introduce these elements into the environment. Private sector programs are stimulating changes in the business or investment climate, i.e., the rules and regulations that dictate how businesses must operate in any given situation. These elements include taxation, licensing fees, rules on

exports and imports, tariffs and quotas, profit retention, and foreign exchange access. The legal system and its enforceability with respect to honoring contracts are also important elements to consider. Without an expectation that contracts will be honored and carried out as specified, little progress toward agroprocessing will be achieved. Other institutional issues, as mentioned earlier, revolve around financing, transportation, storage, infrastructure (electricity, sewage, water, etc.), ports, telecommunications, and insurance.

Agribusiness Development

To the extent that agroprocessing is carried out by agribusiness, some firms will incorporate these elements in their operations to provide a package of services to smallholders that will allow the system to expand. Many firms will develop contract growing schemes. USAID and IDRC evaluated several of these operations a few years ago, and USAID is now promoting contract growing in Africa and several other places around the world. Two famous models of contract growing are British American Tobacco operations in East Africa and the Kenya Tea Development Authority's smallholder tea program. The analysis carried out showed that many forms of contract growing schemes exist and can be successful. Each addresses a set of the issues identified earlier, and for success, transforms the values of the parameters in the induced innovation model so that rather than inhibit, they create a dynamic that allows the model to function as described for the green revolution setting in Asia. Relatively elastic market demand is introduced, low-cost technologies developed, products transformed, and the support system established. With all of these variables in the right proportion and with appropriate prices, the model functions normatively with a dynamic that develops rapid economic growth.

The Learning Curve

The emergence of agribusiness to assume these functions in the development process, however, is not automatic. Risks are enormous, and in a technical sense uncertainty abounds. Indigenous firms do not always have the capacity to provide all the required services, especially in technology, management, and marketing. In contrast, foreign firms lack production skills, local partners, political savvy, or environmental knowledge. Private sector analysts or researchers have observed that there is a learning curve that must evolve before operations become profitable and sustainable. The costs required to pass through this learning process are high, sometimes enormous. Neither local firms nor international firms, large or small, are willing to make these investments in most cases, resulting in extremely slow development and evolution. Although pressures are mounting to expand the global marketplace for both production and consumption, the costs of penetrating these unchartered waters (or deserts) can still be prohibitive.

The costs incurred during the learning curve need not be borne exclusively by the private firms: donors can contribute. Currently, agricultural extension systems are financed by government, and the donors contribute handsomely to cover these costs. Why not create donor support of private agroprocessing firms so that they could hire former extension agents to provide technological advice to farmers on the firms' particular products? An agroprocessing firm designed and established to produce vegetable oil must have access to oilseed crop production on a specified schedule and with the quality required. Extension agents will be required to organize production, but the firm will be reluctant to cover these costs because these services are normally provided by the government. Although the private sector in the United States contributes roughly one-third of the costs of local extension agents, it is still not common for companies to engage an entire staff of agents to grow their crops. Donors could contribute in this area by providing grants to private firms that engage in extension activities during a start-up phase, allowing companies to cover the risks associated with initiating a new operation.

A similar situation exists for agroprocessing firms involved in manufacturing activities. When the Koreans introduced the textile industry in Bangladesh, they brought several hundred technicians with them for a few years to train local staff from the ground up. They were extremely successful from the Bengali viewpoint; the textile industry flourishes in Bangladesh. But there were costs associated with this technology transfer. This same process is beginning in Africa. Korean and other Asian firms are seeking a manufacturing base in Africa to lower their production costs and to penetrate new markets. They are also losing their current markets because of quota restrictions and GSP reductions. European and North American companies are just beginning to recognize this opportunity. They will need, however to expend considerable resources on these learning costs, some of which could be covered by donor funding. Staff training, technical assistance in prefeasibility and feasibility studies, management assistance, technology introduction and adaptation, and quality control are all activities that could be supported by donors.

This approach follows on collective experience in the agricultural development process. There has been an evolution since the early 1960s in community development, followed by integrated rural and agricultural development and then a basic needs approach, farming systems, and food security. Presumably, we have learned how to do this thing called "economic growth and development." When these programs have been successful, they have begun on a local basis with rather low-valued crops and have then moved to a regional basis with more market-oriented crops, becoming really contributive to economic growth when nationalized programs with export crops have been the last phase. This is a learning curve approach, which needs to be stimulated with donor funding as the private sector plays its complementary role of providing markets, technologies, service, and management.

Backward Linkages

Once an agroprocessing initiative is activated, myriad backward linkages mushroom. The supply of raw material comes from farmers. In some instances companies will farm as estate farms, but the potential for contract growing schemes is tremendous. The number of crops with elastic international demand for certain types of semiprocessed products is extensive. Table 1 provides a rough estimate of some of the employment linkages each could generate if an agroprocessing firm were to contract grow the supply with the smallholders.

These rough estimates for Africa show a direct employment figure of over 6 million. When the multiplier effect is taken into consideration for services and consumer goods production, this figure should be increased four to five times. Agroprocessing for smallholders can have a significant impact on economic growth in developing countries, especially in Africa.

Recent Examples and Recommendations

This section will discuss some examples from Africa during the last two and one-half years. Over 40 companies (all American) are interested in joint ventures or sourcing contracts. They include:

Heinz	Masco Home Furnishings
Hershey	Elegante
Suchard (Phillip Morris)	Ladd
Cargill	Cramer
Conagra	Weyerhaeuser
Bergerco (pulses, peanuts, canneries)	Wellman Ind.
Berdex	Vanmark
Pioneer	Quirk Tire
Dekalb	Rohm & Haas
	MGR (Pyrethrum)

Seaboard	Sun World
Cone Mills	Universal Leaf
Levi Strauss	Lummus
Continental Grain	McCormick Spice
Rolfes (grain elevator machines)	Del Monte
Guilford Mills	Amoco
Vinaport Vessels	R & H Foods (cocoa & flavors)
Burlington Mills	Ward Enterprises (leather)
Hormel	Erly Ind. (Kraft Juices)
Sara Lee (Stedman, Haynes)	Winsor Grain (specialty products)
Vanity Fair (Lee, Wrangler)	Silopress (Silaze)
Agrimart (growth hormones)	Coleman Fisheries

This does not even scratch the surface with regard to the potential number of companies. With the specific products, the companies have unsaturated demand at very high price levels. But they want quality and consistency, two elements that have traditionally been absent from African products.

To develop these ventures, an agribusiness diagnostic is necessary and entails an analysis of commodity production in terms of quantity and costs and potential markets. This diagnostic identifies the producers and processing firms and analyzes which firms are interested in expanded markets and joint venture partners. Then, an in-depth look at each specific market is conducted. Once the commodities and markets are identified, the search for a foreign partner begins (some prefer and limit themselves to American partners). This is done by hiring an industry leader to identify companies in that industry that need to expand their production capacity off-shore or companies that must find new sources for their input products. These industry leaders are not from consulting firms, but rather are businesspeople currently managing their own firms in their respective industries. These leaders are then trained in the concept presented, and they begin to analyze their industry and identify who among their peers might consider an off-shore, African-based joint-venture. They then arrange for an investment mission to one or several sites to begin negotiations for establishing the new business.

USAID assists in many ways in addition to the support for the industry leader. It sometimes assists representatives from the companies in making their trips to Africa. It carries out product and market surveys. It supports agribusiness associations, such as the AgriEnergy Roundtable, the AgriBusiness Council, and the American Society of Agricultural Consultants, to help identify industry leaders and potential companies. It also helps to arrange for financing, currently supporting the APDF, the Africa Growth Fund, OPIC, MIGA, FIAS, AMSCO, DEG, and EDESA. There is a project to help set up venture capital funds in Africa and, with OPIC, a project to promote EPZs. USAID has led the way in Africa for debt-swaps. From all of these sources, USAID can help a company find the necessary financing for its new operations. It promotes minimal company exposure and highly leveraged local investment and currency, showing companies how to insure the foreign capital invested. One particular project involved a \$1 million USAID grant for technical assistance to the company that agreed to invest \$250,000 capital in the joint venture, representing 20 percent of subscribed capital of the new firm. Another project involved a company leasing a plant for a minimal amount but with a contract for complete management. In another country, a company is in its final stages of determining whether to set up a \$100 million denim factory. If it does, it will require 80,000 bales of new cotton per year initially, doubling over five years. In Ghana alone there are 10 potential companies representing a chocolate liquor plant, two aquaculture operations, an off-shore fishing operation, specialty crops for feeds, women's horticulture crops, a rubber processing plant, a cassava starch plant, expansion of a wood-processing plant, and the development of *Jatropha Curcas* (a vegetable oil substitute for solid-based diesel fuel that emits no smoke).

Table 1. Crops with Market Potential and Employment Estimates in Sub-Saharan Africa

<u>Crop</u>	<u>Product</u>	<u>Employment (000s)</u>
Livestock	Leather	50-100
	Meat, chilled	
	Meat, canned	
	Dog food	
Cotton	Short staple	150-300
	Long staple	150-300
	Textiles	100-200
Industrial oils	Vernonia	300
	Jatropha	500
	Ethanol	500
	Jojoba	20
Rubber	#20	40
Cocoa	Beans	100
	Butter	30
Produce	Vegetables, fresh	200-300
	Canneries	200-300
Juices	Fruit, citrus	100
	Fruit, tropical	50
	Fruit, exotic	30
	Fruit, fresh	100
Nuts	Cashews, macadamia	50
Pesticides	Pyrethrum	30
	Neem nut	20
	Wool	75
Sheep	Furniture	50
	Plywood	20
	Moulding, etc.	30
	Peanuts	
Beans		50
Pulses		100
Feed	Grain	500
	Silage	500
Poultry		50
Goats	Mohair	20
Sesame	Seeds, oil	200
Seeds	All types	200
Gum arabic		10
Vanilla		5
Tumeric		5
Tobacco	Leaf	150
Sorghum	Grain	200
Millet	Grain	100

Some of the new technologies being promoted include:

Jatropha Curcas	Sta-wet
Silopress	Stress-ease
Vernonia Galamensis	Plastic bottle recycling
Neem Nut	Ethanol
Flavor essences of coffee, cocoa, and exotic fruits	Pyrethrum

To entice these companies into making a commitment to invest in or source from Africa, even for the large billion-dollar firms, requires much encouragement. An incentive grant of \$200,000 to \$1 million, to help defray establishment or learning curve costs, is essential. Some countries have institutions that offer equity grants that serve this function, such as the CDC of England, FMO of Holland, DEG of Germany, and ODA of Japan; Korea also assists its firms in their expansion activities. The United States, however, does not have an instrument to serve this function. This is a catch-22 situation: the private sector should provide these funds, but it finds these activities too risky. Nevertheless, governments generally believe it is the private sector's function. Perhaps, though, as understanding of the agribusiness process improves, we will find ways to finance all of its components.

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CLOSING SESSION

FINANCING AGRICULTURAL DEVELOPMENT IN THE 1990S: TOWARD A WORLD BANK STRATEGY

Michel Petit

The title of this presentation is too ambitious. It is indeed extremely difficult to obtain comprehensive data on the flows of financial resources that support agricultural development in the world. For this reason, this presentation will focus on the role of the World Bank. However, this is legitimate on two counts. First, the Bank is clearly the leading financial institution, and there is no sign that this role has been assumed by any other institution when World Bank lending began to decline nor that this will happen soon. Second, the World Bank is obviously the institution that we can hope to influence. I would like to review the evolution of Bank lending in support of agriculture. We have been concerned for some time by the decline in the volume of lending. More recently, an additional concern has been raised because of evidence that the quality of agricultural projects is declining. After that review, I would like to suggest three directions for the future of the Bank's activities in the sector. With these three directions, I hope to contribute to defining a strategy for agriculture in the Bank.

Decline in Lending for Agriculture and Rural Development

The data documenting this decline are well known. They can be found, for instance, in the last annual sector review, which was circulated widely within the Bank. For the period 1976 to 1980 the share of the sector in total Bank lending was 30.2 percent, and it declined to 20.5 percent during 1986-90. In recent years, it has been less than 20 percent, around 17 percent in FY90, and we expect similar figures for FY91. The causes of this decline are also well known. First, project size has been reduced. This has occurred as lending has somewhat shifted toward Africa. The number of projects in Africa has increased, whereas there has been a decline in the number of projects in Asia and in other regions. For good reasons projects in Africa are smaller than in other regions.

The second reason is the emergence and the growth of adjustment or policy lending. When adjustment lending increases, of course, project lending is less than 100 percent of Bank lending, and because lending for agriculture and rural development per se is part of project lending, one would expect that this sector's share in total lending would decline. But the decline in lending for agriculture and rural development has been more than proportional to the decline in total project lending. Adjustment lending--bringing about policy changes--has in general been favorable to agriculture. There is ample evidence that in many developing countries macroeconomic policies and other sector policies discriminate against agriculture even more than agricultural policies, the record of which is mixed on that score. Correcting these distortions should lead to improved terms of trade for the agricultural sector and therefore benefit not only agricultural growth, but also agricultural producers and rural areas depending on agriculture as a primary source of economic activity.

A third cause of the decline in lending for agriculture is the drop in agricultural commodity prices in the early 1980s. Despite yearly variations in those international markets, prices for agricultural commodities

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have generally remained low since then, leading to low economic rates of return when investment projects are being considered.

The fourth reason for the decline in the share of Bank lending for agriculture is linked to the fact that if agriculture and rural development projects are to be effective, they must be staff-intensive. Everybody in the World Bank knows that he or she works under very tight resource constraints, particularly regarding what we call the administrative budget. This clearly does not favor staff-intensive projects.

In addition to the concern about the volume of lending, the recent annual report of OED raises serious issues and concerns regarding the quality of agricultural projects. The OED annual report is based on the cohort of projects reviewed in 1989. The worrisome figure of that report is that 44 percent of the agricultural projects of that cohort have been rated as unsatisfactory, compared with a 30 percent rate of unsatisfactory projects during 1974-88. In addition, this rate of unsatisfactory projects is much higher than for other sectors. The OED annual report points out that many unsatisfactory projects are in countries where the macroeconomic and policy environment is not favorable: it discriminates against agriculture. This confirms what was said above about the benefits to be derived from adjustment lending. The OED report also points out that many unsatisfactory projects have been so rated because of problems either at the preparation and/or at the supervision stage, reflecting the need for good and sufficient staff work.

Despite these concerns about both the volume and quality of lending, agriculture undoubtedly remains very important to the objectives of the Bank. As a result, this sector faces a serious dilemma. We are supposed to remind our managers that agriculture remains an important sector, but we must recognize that throwing money at problems is not a good solution. This mundane statement of course is not original, yet it is relevant, particularly if we examine the situation of our current portfolio. The three major types of projects in that portfolio have serious limitations. They involve agricultural credit, integrated rural development, and irrigation and drainage.

Agricultural credit projects, like other projects relying on development finance intermediaries, have well-known difficulties either because farmers, and more generally borrowers, are not really forced to repay their loans or because the burden of interest subsidization is unbearable. In India, for instance, debts of farmers are often forgiven at the time of election; that does not contribute to the sustainability of the financial intermediaries whose assets are thus regularly reduced. In other instances, the clear example being Mexico, interest rates were so heavily subsidized that financing the subsidies had become a major drain on the public treasury. In both cases, these practices must change. The Bank must be more demanding and insist on better credit projects, even if that means a lower volume of lending.

I do not need to dwell on the problems faced by integrated rural development projects. The criticism is well known. It was expressed vividly in a widely distributed 1985 OED report. This actually may have led, unjustifiably, to giving integrated rural development a bad name. The main objective of integrated rural development remains justified. It is indeed necessary to pay attention to all sectors in rural areas if one wants to promote general welfare and more particularly that of poor rural people. What was probably underestimated were the difficulties faced by government agencies at the regional level in delivering the services that were viewed as necessary to integrated development. Whatever the merits of this argument, many projects failed, and one should not push for big volumes of lending through this channel.

In irrigation and drainage, many projects have not included drainage. This has led, as could be expected, to environmental damages such

as waterlogging and salinity problems. This must be changed. In addition, favorable areas suitable for irrigation have been equipped, and only areas less favorable remain to be equipped. With lower commodity prices, the economic rate of return on these projects, particularly if drainage investments are included, is low, and this explains why we have reduced our volume of lending to this subsector.

Finally, there is the well-known difficulty that hampers our ability to increase lending to agriculture projects and to enhance at the same time the quality of projects, namely, the decline in the technical capacity of Bank staff. Good projects require competent people; the range of competencies needed is very wide and is not restricted to technical expertise. But the decline in the number of technical experts should be a concern to all of us. Given this somewhat pessimistic assessment of the situation and of the opportunities for the sector, we must rearticulate a strategy that is adapted to present circumstances and that will maximize the Bank's contribution to agriculture and rural development.

Toward a New Strategy

Spelling out a strategy for the sector is indeed fraught with many difficulties. Conditions in the world vary. Decisions in the Bank are decentralized. Hence, an overall Bank strategy risks being very general and not really implemented. In a sense, the set of Bank activities in a specific sector will always be the aggregate result of decentralized decisions taken at the level of country departments. Yet it is necessary to provide general guidance to those working in agriculture and also to articulate a position for a meaningful dialogue with all interested parties inside and outside the Bank, be they staff working in other sectors, Bank management, Executive Directors, officials in borrowing countries, or participants in the development community at large. The overall objectives of the strategy must be those of our institution, namely, first and foremost, to contribute to poverty alleviation, particularly poverty in rural areas. A second objective, equally important, is the careful husbandry of natural resources. The natural resource base on which agricultural production relies must be protected if the fight against poverty through development is to be sustained. I would like to suggest three main components for the pursuit of these general objectives in our sector: (1) to maintain the momentum for policy and institutional reform, (2) to promote technological change, and (3) to properly manage natural resources. These three components include many elements that are already part of the lending program in many divisions, but perhaps elaborating on them briefly may be useful.

Policy and Institutional Reform

Policy reforms are critical because of the distortions in economic incentives discussed earlier. What we have learned, however, is that the political economy of policy reform, particularly for policies affecting agriculture in developing countries, is often not favorable to agriculture. Correcting the distortion is always opposed by those who benefit from the policies. We have learned that in the process of structural adjustment all distortions are not corrected at once and pressures must be maintained to make sure that the distortions discriminating against agriculture are corrected and that they are not worsened. Institutional reform is really a major component of any development process. One can perhaps argue that the main difference between developed and developing countries is related to the level of institutional development. To pursue institutional reform we have various lending instruments: the structural adjustment loan, the sectoral adjustment loan, and hybrid loans, as well as the policy dialogue, which has existed before policy lending. Regarding policies the situation varies, of course, by country. But a few generalizations can be made here. Clearly, in some circumstances, specific poverty alleviation operations are justified, as was the case last year in the Cameroon and in Uganda.

Food security objectives are important ones. Food security does not mean food self-sufficiency, and borrowing countries must be encouraged to seek food security through their search and exploitation of comparative advantages, their ability to buy, possibly to import food and pay for it. To develop exports through reliance on trade is usually an important component of any food security strategy. The level of uncertainty on international commodity markets, however, is such that it is probably wise for many countries to seek a greater degree of self-sufficiency than would be the case if international commodity prices were stable.

Other important policies deal with input subsidies, credit distortions, and land tenure issues. Let me touch on these briefly. Input subsidies create price distortions, and generally we in the Bank suggest that these be eliminated. We should however recognize that in some instances there may be a second-best solution offsetting macroeconomic and sector distortions that political economy prevents from being eliminated. If that is the case, however, one must be very attentive to the distribution impact of input subsidies within the agriculture sector. Input subsidies often benefit those who use large input quantities or who have access to the subsidized input, and generally those are frequently the stronger segment of the agriculture producers, because they are wealthier and/or politically influential.

On credit, I do not need to elaborate much further on the conclusion of the so-called Levy report. Credit programs that are heavily subsidized or under which farmers are permitted to eliminate their debt each time there is an election are clearly not sustainable, and we should not pursue them, as discussed earlier. This does not mean, however, that targeted credit is always undesirable. The example of many industrial countries shows that targeted agricultural credit has had a critical role in the development of their agriculture.

For land tenure, the general idea is that security of tenure is favorable to the modernization and intensification of agriculture, and hence to growth in agricultural production. But this is only a general statement. Recent research by AGR in Africa indicates that perhaps the best way to ensure the security of tenure is not through land titling as we have recommended in Asia, but through the strengthening of the traditional customary rights and institutional arrangements regarding access to land.

With all of these policy issues, the main difficulty is to reconcile two contradictory pressures: The positions on economic policies affecting agriculture expressed above are quite general: they must be specified in each particular situation, and we must always remain pragmatic. But the search for pragmatism should not lead us to accept anything. Our colleagues in Operations, who have to judge situations on a case-by-case basis, indeed have the difficult task of continually balancing tradeoffs.

Promotion of Technological Change

It may appear too narrow to identify this as one component of a strategy. Some would argue, particularly in other sectors, that activism in the field of technological change is not called for, particularly in the Bank because of its nature as a financing institution: the Bank is not a place to define a strategy in terms of technological changes to be promoted. According to that thesis, we have to accept the decline in the number of agricultural technicians as reflecting the evolution of the institution, which may have been active in the past in this area but will not be in the future. Although these arguments may have validity and do raise important questions, at this stage we cannot afford to ignore those technological change issues. If we feel that we cannot accept leadership in that area, then we must drastically change our ways of doing business because we profoundly influence the process of technological change in agriculture through various activities that are clearly important. Our support to international agricultural research through the CGIAR, our lending to borrowing countries to support national agricultural

research systems, our support to agricultural extension in Africa and in other regions, and more generally our investment in the area development projects have very often implied the adoption or the promotion of one or several technological packages.

The sad reality, however, is that although we have various levers to influence technological change in agriculture, as an institution we lack a strategic vision for technological change. Such an expression may be vague and difficult to understand. Let me try to illustrate it with an example. One serious concern is the extension of agriculture in the rain forest areas of Latin America, Africa, and even Asia. Under demographic pressure, the fallow rotation period becomes shorter: this is one of the major causes of deforestation in the tropics, as well as of loss of soil fertility. Unless new technologies are found, possibly by researchers, and adopted by farmers, this deterioration will not be checked. It is therefore critical to find new technological packages that permit intensification of agriculture. As Pedro Sanchez has indicated in this symposium, possible and encouraging approaches have been identified. Defining a strategy for technological changes in this area includes a clear identification of the needs and of the technical potentialities, as well as a coordination of research activities ensuring support to promising approaches and the development of proper institutions. From this perspective, another difficult issue with which we are confronted is the insufficient synergies among the various institutions involved in this process, particularly the synergies between agricultural research and agricultural extension. Several extension projects include applied research components and aim at tapping the research expertise, for instance, the training of subject matter specialists by researchers in the T&V system. But we should probably be very concerned that in many developing countries we continue to support different institutions with separate mandates for research and extension. The contrast with the U.S. land-grant universities is striking, even if, admittedly, this is not an institutional model that is easy to transfer from one culture to another.

Defining a strategic vision that has to focus on the content of the research needed will indeed be a challenge in many instances. What about the situation in rainfed areas? Clearly, protection of the resource base is important; hence, watershed management is important. What about, however, improving the yield of crops? What are the prospects regarding the integration of livestock in the farming systems? How should emphasis be distributed? What proportion of resources should be devoted to these areas, contrasted to more fertile areas with higher potential? All these are difficult questions. More attention needs to be given to them by the Bank.

Management of Natural Resources

This theme is important because of the absolute necessity to conserve the resource base for continuing growth in agricultural production. We will be paying particular attention to water resources; therefore, we need to continue to work on irrigation and drainage. Given recent environmental concerns, particularly related to waterlogging and salinity, but also given the high rate of failure of important projects in this area, future projects should be concerned mainly with the rehabilitation and modernization of the existing system. In addition, projects should focus on innovative management, including farmers' participation and new relationships among various actors involved, particularly between farmers and irrigation departments, leading to new ways to achieve cost recovery while giving more weight to farmers in the decision regarding maintenance of the system. Interaction between management and technological change is extremely important and needs attention. In this respect we must perhaps rely more on the lessons learned from research conducted at the International Irrigation Management Institute (IIMI) and give clearly more importance to technological research, as promoted by our recent initiatives regarding the International Program for Technical Research in Irrigation and Drainage (IPTRID).

The second area attracting much attention has to do with forest resources. Here striking the proper balance between conservation and development is the critical issue. The forthcoming forest policy paper should provide some guidance on this. But whatever the value of the forest policy paper that will eventually be adopted, it is impossible to determine from Washington the proper balance between development and conservation in a specific situation, and it is still more difficult to decide what kind of portfolio of activities to be supported by a Bank loan will achieve the proper balance, once it has been defined.

The third area has to do with soil and land resources. This is an important area where farmers tend not to adopt the techniques and the practices that are recommended and that would ensure conservation of resources. This is a challenging issue in which the Bank has started to work, both through its lending program and its research program, but we will need to increase our expertise.

Finally, both fishery and livestock activities can be viewed as resource management, although one could also consider them under the heading of production. These subsectors do not receive as much attention as they deserve. The Bank has had many difficulties in these subsectors, but the level of attention given to them must increase.

Conclusion

Given the tone of the preceding paragraph, it may sound paradoxical to conclude by a call for optimism. Yet I would like to do so because the difficulties that we face should not lead to pessimism; they are inherent in any development process and should be viewed as such. The causes for optimism are real indeed. First, we have a much clearer sense of purpose now than a few years ago. The contribution to poverty alleviation in a sustainable fashion is increasingly accepted, and it gives us a sense of purpose. Another cause for optimism is the greater degree of intellectual humility in this institution, which is clearly in order. The very tone of my presentation calls for intellectual humility. I have the impression that Bank staff are now less arrogant in what they say than they were a few years ago. The third reason for optimism is the increased awareness of the need for internal collaboration, as well as the need to make such collaboration effective. After reorganization, the modalities and procedures for collaboration among various parts of the Bank were quite uncertain. The dust has now settled, maybe not completely but to a large extent, and we are much better able to understand what each of us can do. Our main role in AGR is to develop and formulate the agricultural policies of the Bank and to explain them to the outside world. This leads to a very diverse portfolio of activities, meaning that our colleagues in Operations sometimes are frustrated because we spend only a fraction of our time in direct support to Operations. In addition, given our small size, we can only contribute a small fraction of the total staff input that goes into Operations. But that fact is becoming increasingly recognized and accepted. Let me tell you very forcefully that our intention is to seek complementarities and synergies, and obviously we need your cooperation and collaboration.

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