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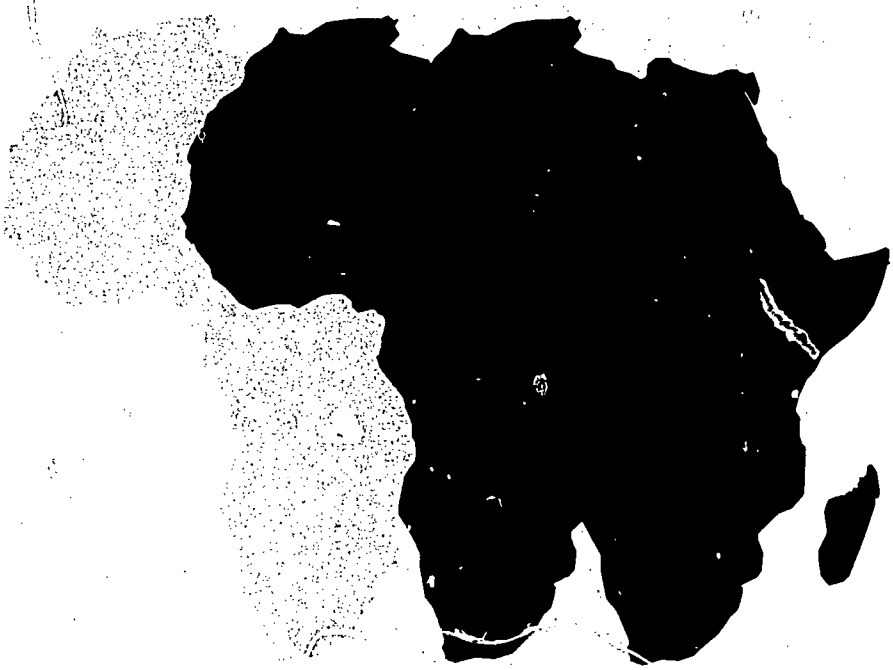
Towards a new agricultural revolution:

Research, Technology Transfer, and Application for Food Security in Africa



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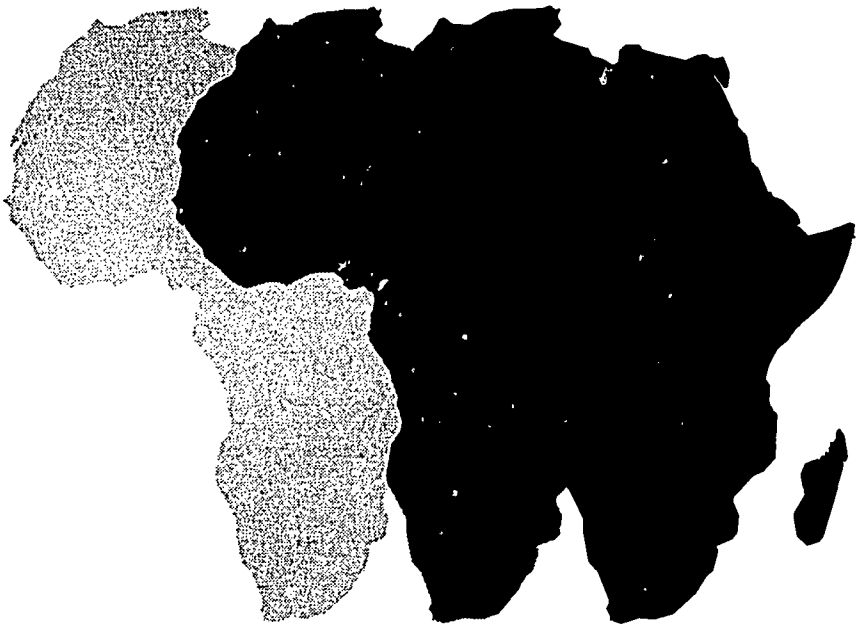
Towards a new agricultural revolution:

Research, Technology Transfer, and Application for Food Security in Africa

IFPRI/ISNAR



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Foreword

This paper was originally requested by the World Food Council and presented at its international consultation on "Meeting the Food Production Challenges of the 1990s and Beyond." It was prepared jointly by the staff of our two centers, with Peter Oram taking the lead. Both ISNAR and IFPRI have collaborated closely with development policymakers and leaders in the national agricultural research systems of many sub-Saharan African countries, so the writing of this paper came naturally to us with so much data available in the two institutions. It also provided a useful opportunity to compare notes and learn from each other's experience.

The challenge of food security in sub-Saharan Africa is daunting, but we believe that the natural resources of the subcontinent have been underestimated, even where some of them have been degraded. Given a strong institutional infrastructure for research and transfer of technolgy (and above all, the development policy framework to support it), there are major opportunities for increasing food production. Unfortunately, the potential for food production cannot always match the needs of the population. The foremost task now is to strengthen the NARS in the region.

In preparing this paper, Peter Oram had considerable input on its relevance and content from Dr. Mandivamba Rukini, Dean of the Faculty of Agriculture of the University of Zimbabwe, and Dr. J. Eckebil, Deputy Director General of the International Institute of Tropical Agriculture at Ibadan. Their African perspective has been of great value. The assistance of the United Nations Development Program with financial resources was also extremely helpful.

After the meeting of the World Food Council, ISNAR decided that the information in this paper should be given wider distribution. Thus, it is now published as an ISNAR Document.

We believe that the approach used in producing this paper has been useful and productive, and we look forward to similar efforts in the future.

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Executive Summary

Sub-Saharan Africa has not historically been a major food-deficit region, but it has become increasingly dependent on food imports over the last 25 years. It is the only developing region where the number of malnourished people has increased progressively and per capita output of staple foods has fallen steadily over three decades.

This paper examines the reasons for these ominous trends, looks at the possible consequences of their continuation for future food security, and suggests countervailing policies and approaches. Finally, an action agenda for research and technology transfer is proposed for the current decade. The approach is essentially regional. No attempt is made to identify research priorities at the national level, where decisions have to be made that transcend food security.

Past Trends in Food Consumption, Production, and Trade

Food consumption rose an average of 2.5 percent per year between 1961 and 1985, while production increased at only 1.7 percent per year. This led to a net trade deficit of nearly seven million tons in 1979–83, compared to a trade surplus of nearly 1.4 million tons in 1961–65. Dietary energy supplies stagnated or declined in 21 out of 38 countries. Self-sufficiency levels fell progressively, even in rural areas, with farm families having to buy food with their meager cash reserves in order to survive.

Food deficits are not equally distributed among major subregions of Africa, nor among staple foods. Neither have drought-induced crop failures been evenly spread — semi-arid West Africa has been especially affected.

Lagging growth in the production of traditional African cereals (millet, sorghum, and white maize) has been the main source of shortfalls in production. This, coupled with the inability to match the growth of rural demand, problems of feeding political refugees, and rapid urbanization with the consequent pressure for foods of convenience, has led to escalating imports of wheat and rice. Production of other foods, particularly roots and tubers, has risen modestly to help bridge the gap, but these starchy foods, grown mainly in the wetter zones of Africa, are perishable and bulky to transport. They also have less appeal as foods of convenience.

The Alarming Outlook to the Year 2000 and Beyond

Projections of the continuation of a situation where Africa has the highest average population growth rate in the world and the lowest and least stable growth of food production are alarming. Independent analyses by IFPRI and the World Bank indicate a gap of 50 million tons by the end of this century, and the Bank projects an almost inconceivable deficit of 245 tons by 2020, assuming a growth rate of only two percent in food production and constant 1980 fertility rates. A production growth rate of four percent would approximately halve the gap; if this were to be matched by a sharp decline in fertility rates, the deficit would be reduced to eight million tons by 2020, about its present level.

The report stresses the importance of maintaining satisfactory growth in agricultural exports, both to help finance food imports and to purchase fertilizer and pesticides to increase the growth of domestic food production. It notes that FAO predicts an in-

creasing number of food-deficit countries in Africa by the year 2000 if input use is not increased. It also draws attention to the increasing incidence of poverty and malnutrition in drier regions of Africa where arable land per capita is declining and the natural resource base is deteriorating.

Droughts since 1965 have been the trigger of famine and the failure of food security rather than the sole cause, but the threat of greater climatic instability due to global warming makes the development of a sound, broad-based strategy for food security all the more urgent. There is hope for the future, but achieving and sustaining a four percent growth rate in food production presents a daunting challenge in a region where both land and labor productivity are low.

Recent Progress in the Pursuit of Food Security: Sources of Growth

Land Area Expansion

A review of the sources of growth in agricultural production shows that land area expansion has been the principal contributor to growth since 1960, although it has slowed down to only about 0.5 percent per year since 1977. In some regions, e.g., the East African highlands, this is due to a shortage of new land; in others labor is a constraint. Scarcity of land and labor is reflected in the reduction in the area of restorative fallow, an increase in noxious weeds, and the abandonment of soil and water conservation measures. "New" land is brought in at the expense of grazing lands and forests, especially forests. Short of an unlikely revolution in the prevailing structure of African agriculture, cultivated area is not expected to increase much faster than one percent per year over the next decade.

Intensification in Small-Farm Agriculture

In most other developing regions, a slowdown in the expansion of cultivated area has been accompanied by a sharp increase in intensification through irrigation and technological change. This has not yet been widespread in Africa.

Irrigated land has increased at around one percent per year over the past 15 years, but it still represents only three percent of total arable area. Dam-based modern systems tend to have astronomical costs per hectare and low returns, and a 50 percent increase in area under major projects by the early 2000s would increase food security only marginally. There may be greater potential in the long run from relatively low-cost exploitation of fertile valley bottoms for multiple cropping in the humid and subhumid lowlands.

Soil fertility is a declining asset in much of Africa, although the reasons for the decline vary widely in different ecological zones. Inorganic fertilizer use is lower on average in Africa than anywhere else, and its growth rate is declining. Ideally, it should be used in combination with organic manure, which is often scarce. This is a situation with serious implications for future food security: FAO estimates that a sixfold increase in fertilizer use is needed to achieve a 2.9 percent annual growth of production over the next two decades.

Technological change, on which great hopes are pinned, has not so far proved to be an engine of growth for food production in Africa, and although there have been some notable successes with export crops (and with hybrid maize in a few countries), attempts to transfer technology from other developing regions have not generally paid off. Levels of adoption by farmers have been low, and development projects have had a dismal record of failure.

Comparisons with the Asian Green Revolution show why progress in Africa has been slower and is likely to prove more difficult. Africa has less fertile soils, a much smaller proportion of irrigated land, a heavy dependence on highly variable rainfall, a less-developed infrastructure, and a weaker institutional base. And unlike wheat and rice (the predominant food staples of Asia), Africa's traditional cereals and root crops have been neglected by research elsewhere. In addition, African farming systems are generally more complex than those in Asia. Yet the report cites reasons for optimism concerning technological potential, noting evidence of a large gap between farm and experimental yields, with an expanding range of improved genetic material and promising responses to fertilizers, herbicides, seed treatments, timely planting, erosion control measures, using oxen for plowing, and closer crop-livestock integration. The willingness of African farmers to innovate where ecological and economic circumstances are conducive to change has been demonstrated widely.

The report discusses why the current realities of the use of technology by African farmers do not reflect the apparent potential. It concludes that there *are*

components of technology available for use on key food crops but that many of them need considerable adaptation to local needs. Some will not be adopted by farmers unless measures can be taken to alleviate labor constraints and make their use attractive and economical. Thus, it is essential to distinguish between *availability* and *acceptability* in assessing the feasibility of technical innovations.

There are pressing problems that must be addressed to increase rates of adoption by farmers:

- Insufficient development of research-extension-farmer contacts results in research programs that do not focus on the country's main needs.
- Poor quality, high cost, and uncertain supply of seed of improved varieties inhibits their use.
- Seasonal labor bottlenecks in rainfed systems impose constraints on the timeliness of planting, weeding, and harvesting.
- Low soil fertility, due to very limited use of inorganic fertilizers, limits the benefits from improved seed and other inputs.
- High costs of imported inputs due to long transportation routes makes it uneconomical to use them, especially in drier areas where risks are greater. Poor infrastructure also imposes constraints on marketing perishable produce.
- Lack of credit for purchasing inputs makes it difficult for farmers to obtain them.
- Other obstacles outside farmers' control imposed by government price, fiscal, and exchange rate policies inhibit the adoption of new technologies.
- Institutions that generate and oversee the transfer of improved technology are not well supported.

Rather than aiming to raise current experimental yield ceilings to higher levels, as may now be the need in irrigated areas of Asia, the first priority in Africa is to adopt measures that will make available technologies more acceptable to producers while research gears up to tackle unsolved problems.

Building the Institutional Base for a Technological Revolution

Research capacity has increased since the mid-1960s, with numbers of national scientists quadrupling by 1985 and research expenditures tripling. However, the development of indigenous institutions had a late start in Africa; about 60 percent of national agricultural research systems (NARS) have under 120 scientists, and much remains to be done to strengthen them, both quantitatively and qualitatively. In the next decade, this means training increasing numbers of African scientists to replace the current large expatriate component, expanding a number of NARS, and selectively filling existing gaps in scientific capacity to tackle priority commodities and problem areas. The report identifies several important areas of weakness in this respect.

While financial commitments to agricultural research as a proportion of the value of agricultural product are quite high in Africa compared to other developing regions, there are worrying reports of inconsistency and instability in government support. In recent years, the salary components of research budgets, especially for support staff, have expanded too rapidly, at the expense of operational funds, and this has led to reduced research productivity. Heavy dependence on donor funding and expatriate staff threatens sustainability and creates a sense of false security.

The report notes several requirements for further strengthening of African research capacity:

- a long-term commitment to institution-building by governments and donors;
- improving the planning and policy capacity for research along with linkages with national policymakers;
- developing national staff training plans to selectively expand NARS and upgrade competence;
- reinforcing research downstream at the farmer level with highly trained staff experienced in field work;
- strengthening universities to do relevant research and postgraduate teaching as an integral part of the NARS;
- concentrating research efforts on a smaller and

less diverse range of priority goals;

- expanding linkages with the IARCs in research, information, and training;
- participating with other institutions in national or regional research networks, but not at the expense of a strong national research capability;
- improving donor cooperation and information exchange.

Research-Extension Linkages and Technology-Transfer Systems

Concern is expressed about possible imbalances in financial support to extension versus research since 1980. Since both systems are interdependent, their support must be evenhanded so that neither is impeded by the other's inadequacy. It is suggested that more empirical evidence is needed to support the expenditures being proposed for research and extension and to determine suitable relationships between investment in the two systems.

Problems affecting the effectiveness of technology transfer include the following:

- difficulties in developing good research-extension-farmer linkages;
- the top-down, hierarchical nature of extension bureaucracies;
- poor logistical support to lower-level field staff, including lack of transportation and telephones;
- relatively low technical competence of field staff, compounded by weak subject-matter specialist advice;
- failure of conventional extension services to cater to special social groups and particularly to meet the needs of women farmers;
- limited or no participation of universities in extension education;
- inability of technology-transfer systems to overcome external constraints imposed by government policies towards agriculture, especially farmers' access to inputs and credit.

The question of how best to meet farmers' needs for advice in Africa and how they can be financed is controversial. Cost recovery is an important issue; this is relatively easy with "profit-oriented" extension services geared to high-value crops, but it is more difficult when addressing semi-subsistence food production or trying to meet the needs of underprivileged groups or resource-poor areas.

There seems to be no ideal model; approaches need to be tailored to specific national needs and, sometimes more narrowly, to local situations. Flexibility in design of technology-transfer systems is therefore very important, and there is an urgent need for comparative evaluation and analysis of the merits of different approaches and the circumstances in which they are most effective.

Food Security Policy

The essential components of food-security policy include the following:

- stabilization of input supplies through research to reduce vulnerability to weather and other stresses and through trade and strategic storage;
- inter- and intraregional planning to exploit African comparative advantage for production;
- maintaining export earnings to finance employment-creating investment, food imports, and yield-increasing inputs;
- creating income and employment in rural areas where the bulk of poverty exists;
- establishing special measures to protect the poorest of the poor;
- balancing growth and equity in assessing research needs and priorities;
- promoting the production of traditional food staples for rural food security and import substitution.

Research Priorities to Promote Food Security

Five policy objectives are proposed and discussed:

1. developing a strong research capacity for food-security policy;

2. improving natural resource management;

3. raising the productivity of farming systems;

4. reinforcing research on storage and processing;

5. improving the effectiveness of technology-transfer systems.

Demand for research nearly always exceeds supply, so an approach is suggested that builds on promising technological progress and existing knowledge of African farming to achieve short-term growth (to the year 2000) through selective concentration of effort in terms of agroecological zones and target groups within zones. This would help differentiate shorter-term opportunities from other important goals, which for various reasons need a longer-term research horizon.

Specific measures related to this approach involve the following:

- systematic characterization of agroecological zones to identify their agricultural potential as well as the type of technology appropriate to their natural resource endowments, infrastructure, demographic pressures, and farming systems;

- development of a selective strategy for maximizing the use of scarce resources within agroecological zones;

- concentration of efforts on a restricted number of key food commodities;

- raising the efficiency of input use;

- Promotion of closer integration of crops and livestock with a concomitant increase in research to improve animal nutrition and to find solutions to major livestock diseases as well as a parallel improvement in animal health, advisory, and marketing services will be needed.

Action Priorities for the 1990s

Research in Food Security Policy

Food security involves highly complex political decisions not only affecting many aspects of the national economy but also the allocation of scarce resources. A strong policy-research capability is essential to providing information and guidance to national planners, as well as in formulating agricultural policy and research strategy.

Since this is a longer-term goal, other measures to strengthen agricultural policy-research capabilities are suggested — in particular the establishment of regional policy-research networks on food security, including NARS and IARCs, with an interlinking mechanism to facilitate exchange of information and experiences across Africa.

Productivity of National Agricultural Research Systems

It is suggested that in addition to carefully planned increases in the numerical strength of NARS (particularly the smaller systems), attention should also be focused on raising the productivity of their staff:

- **to sharpen the focus of research** through better planning and prioritization, concentration of efforts on key commodities and areas of good agricultural potential, increased on-farm research, targeted task forces, and better evaluative procedures;

- **to raise the efficiency of research** through wider use of modern techniques and equipment, access to information, improved laboratory facilities, and better transportation;

- **to raise staff competence** by increasing the proportion of researchers with higher degrees, strengthening managerial expertise, and providing better disciplinary coverage to meet long-term needs;

- **to provide conditions of service that encourage productive research** — particularly by improving financial sustainability and upgrading research and administrative management.

The idea of donor consortia providing one-time grants to sustain NARS over the long term is discussed. This would avoid constant recourse to short-term donor support.

Technology Transfer at the National Level

Attention is drawn to the continuing controversy over which technology-transfer systems are most appropriate to African conditions. It is suggested

that this merits internationally or regionally supported comparative analysis, either on a pilot-project basis within countries or by cross-country comparisons, possibly through a network approach. In addition, there is a need to improve the efficiency of existing technology-transfer systems through the following:

- wider use of media and audiovisual presentations;
- information exchange among countries to increase awareness of common problems and innovations and approaches to tackling them;
- training of managers, subject-matter specialists, and evaluators.

Access to Key Production Inputs

The three key inputs essential to increasing crop productivity are seed of good varieties, fertilizer, and water. Limited access to or control of these inputs by African farmers is a main reason for the failure of agricultural production to grow more rapidly there. In order to improve this situation the following actions are suggested:

- Remove bottlenecks to seed supplies by strengthening seed production services.
- Address the problems of unreliable supply and high cost of fertilizer, probably the single most important input required to raise crop yields.
- Expand knowledge on plant-soil-water relationships and genetic tolerance to stress.
- Develop small-scale irrigation facilities.

The Ecological Potential of Africa

Better evaluation of the ecological potential of Africa would also contribute significantly in both the short and the long term to improved natural resource management, the planning of research, the allocation of research resources, the selection of research sites, and the evaluation and spatial extrapolation of research results within and among countries so as to maximize spillover.

The main tool currently available for this purpose is the characterization of agroecological zones, but there is a scarcity of personnel experienced in these techniques, which are quite resource-intensive. Thus, a high priority needs to be given to training and the provision of equipment and vehicles as the basis for a long-term effort.

International and Regional Cooperation in Research and Technology Transfer

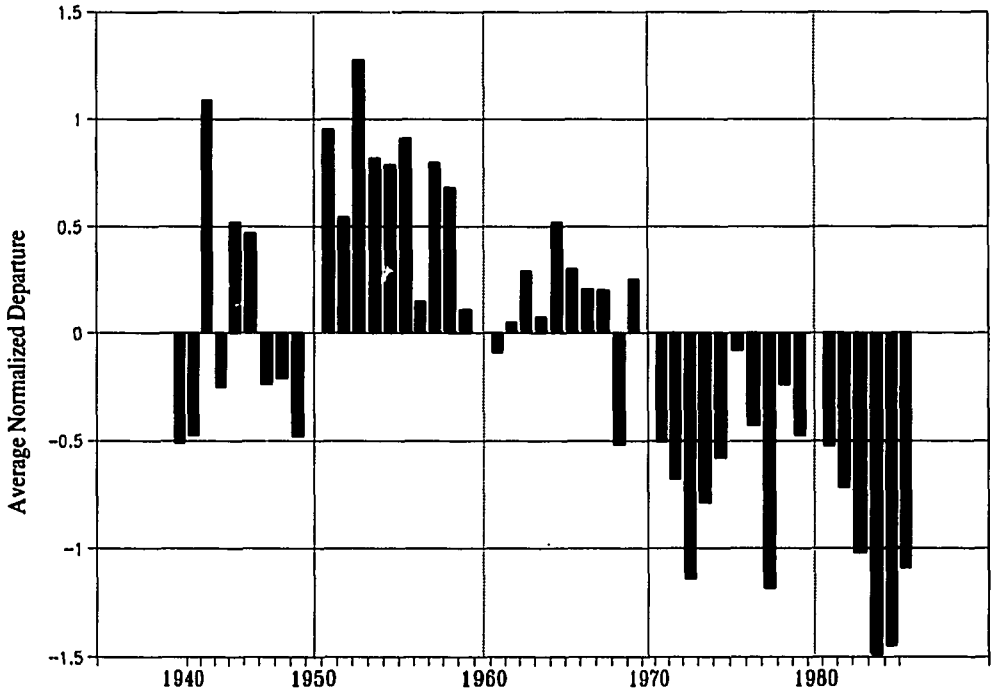
While most of the areas discussed above provide opportunities for regional action, this section examines mechanisms for promoting international and regional cooperation with NARS. In particular, especially with respect to Africa, there is a need to develop approaches that enable small-country NARS to benefit from the economies of scale, critical scientific mass, and sophisticated research facilities commonly available only to large systems. The research network is suggested as an appropriate vehicle for this purpose, in which universities and IARCs can also participate. But a warning note is sounded concerning the dangers of overloading small countries with a proliferation of networks in Africa. Careful coordination among donors, perhaps through the aegis of SPAAR or appropriate regional groupings such as SACCAR or CILSS is therefore recommended.

1

Food Security in Africa: The Current Situation

Introduction

Food security in Africa, south of the Sahara, was not a matter of serious international concern until the tragic Sahelian drought of the late 1960s. As figure 1 shows, there were years of abnormally low rainfall in the 1940s, but the political structure of Africa was different then and the population was smaller. And that time was followed by a long period of above-average precipitation and good harvests, which lasted about 16 years. Food imports were very small then and most countries were practically self-sufficient in their basic staples.



Source: Glantz (1986).

Figure 1. Sub-Saharan rainfall index for twenty stations

This left governments and people ill-prepared for the Sahelian holocaust and the lean years of below-normal rainfall that persisted in the Sahel and in all but the wet tropics for 17 years after 1968. It also created a sense of false security concerning food supply.

Consequently, measures to ensure *food security* in times of scarcity were not in place, and as will be shown in this paper, food security depends on the integration of policies that promote the growth of food production with trade policies, infrastructural investments, and social policies to achieve equitable distribution of food and to protect vulnerable segments of the population. Food self-sufficiency, even in times of plenty, does not guarantee food security to all people.

Thus, drought was the *trigger* rather than the sole cause of a crisis in food security which would have occurred eventually anyway as a result of a number of interrelated factors, including the following:

- the fastest population growth rates of any region in the world, with the highest proportion of the population in rural areas;
- political philosophies that gave low priority to agriculture and rural people;
- increasingly unfavorable domestic, and particularly external, terms of trade for agricultural products;
- lack of investment in rural infrastructure, storage, and transportation in a region with extremely poor internal communications;
- past neglect of research on key African food crops and livestock, resulting in food production that could not be increased fast enough to match the growth of demand;
- inadequate agricultural research and extension services to generate new production technologies and transfer them to farmers;
- critical lack of institutional capacity to train sufficient high-quality staff who could diagnose and find solutions to the complex problems of African agriculture;
- a serious shortage of the inputs required to increase agricultural productivity;
- a very low proportion of irrigated land and slow development of irrigable areas;
- a weak private sector coupled with the heavy hand of bureaucracy on input supply and output marketing (problems common to most African countries for some years after independence and compounded by falling prices for African agricultural products on world markets);
- internal and external political strife (the impact of the latter is clear from the poor records of agricultural growth in most of the countries affected — even in 1990, nine countries were directly afflicted, while others have had to cope with floods of refugees).

Throughout the two decades since the first Sahelian emergency began, the threat of drought has hung over Africa like a sword. Its direct effects have increasingly been aggravated by rising population pressures on resources, the resulting degradation of productive potential which results from this pressure in the absence of technology to raise productivity, and the cumulative effects of successive years of drought on the environment. Whereas recovery from intermittent dry seasons is usually possible, the effects of persistent drought become cumulative and catastrophic.

Since 1970, volumes have been written on the problems of growth and development in Africa, of which the challenge of providing a secure and adequate food supply to all its people is only one issue — albeit a fundamental one. As is evident from the brief analysis above, that issue in itself is complex and multifaceted, transcending the more narrow but central question of raising and sustaining the productivity of agriculture in the region. While this paper focuses mainly on that key question, it also considers the policies and complementary measures required to ensure that unforeseen shortfalls in domestic production do not compromise the broader goal of food security.

At the outset a cautionary note is required. Agricultural progress in sub-Saharan Africa since 1960 has had a checkered history, and there are a number of striking paradoxes. The following provide some examples:

- very fast population growth rates with high unemployment in some rural areas of high popu-

lation density, yet severe problems with labor shortages at peak periods, which, combined with low labor productivity, act as major barriers to the expansion of agricultural production;

- an apparent abundance of land for agriculture, but an actual land scarcity;

- underpopulation in an economic sense due to poor infrastructure and weak internal markets, but overpopulation in an agricultural sense — a majority of African countries cannot grow enough food to meet domestic demand even at current low levels of purchasing power — in some, production per capita has actually declined. These countries include several in the wet tropics where population density is low and drought is not severe — further evidence of the complexity of the problem.

This paper was developed at the request of the World Food Council, which has become concerned about the increasing difficulties being experienced in raising the yields of major food crops and the threat this poses for food security.

So far there has been no "Green Revolution" in Africa. The past growth of food production there has been less than half that required to prevent a major food crisis by the beginning of the next century. However, as we show here, conditions in Africa are not comparable to those in Asia, nor are they as propitious for the kind of narrow, two-commodity technical breakthrough that occurred there. Africa has a more diverse ecological range, with large areas of difficult soils. Its agriculture depends almost entirely on rainfall. Its farming systems are many and extremely complex. There is a very weak base for manufacturing agricultural inputs, and there is a critical shortage of trained and experienced scientists and technicians. Other developing regions face many of the same constraints, but most of these are more severe in Africa.

Food deficits projected for Africa by the year 2000, based on a continuation of past trends, are alarming. Nevertheless, we believe that a stock of knowledge is accumulating — often through bitter experience — which will enable this situation to be reversed over the next two decades. But we do not expect miracles.

Increasing the productivity of both land and labor to achieve and sustain a four percent growth rate in agricultural production, while simultaneously creating more rural employment for the additional people joining the labor force, poses a massive challenge to the policymakers, scientists, and institutions responsible for making new knowledge and technology available and acceptable to farmers.

A "new agricultural revolution" in Africa will have to be built on understanding the complexity of African agriculture from the bottom up. It will also have to be based on better management of its human and natural resources, rather than on quick technical solutions. There will have to be radical changes in domestic policies towards agriculture, of which there are encouraging signs. International goodwill is already abundant. (Perhaps in some respects, it is too abundant and not always effectively utilized!) But to transform African agriculture to meet the exigencies of the next century and to provide greater food security to its people will take time, imagination, a huge investment in human resource development, and considerable patience on the part of governments and donors.

Progress in maintaining or raising the growth rates of agricultural and food production depends heavily on the availability of improved technology and its adoption by producers. Because of this, this paper focuses primarily on the potential for technological change, the development of institutional capacity for research and technology transfer, the measures required to raise the efficiency and productivity of the institutions concerned, and the strategies and policies that provide farmers with access and incentives to use new techniques as they become available.

Food Production, Consumption Trends, and Outlook for the 1990s

The Widening Food Gap

Sub-Saharan Africa has become increasingly dependent on food imports over the last three decades, from both commercial and concessional sources.

For the region as a whole, the self-sufficiency ratio has declined from 98% in the early 1970s to 88% in the mid-1980s. Africa is the only developing region showing a consistent decline in per capita output of staple foods since 1961 (table 1).

Table 1.
Per Capita Output of Staple Foods
(Cereals, Pulses, Roots, and Tubers in Grain Equivalents), 1961-65 to 1986-88

Region/Country Group	1961-65	1966-70	1971-75	1976-80	1981-85	1986-88
			Kilograms per capita per year			
Africa	230	224	219	201	186	192
Far East	222	224	228	240	254	246
Latin America/Carribean	284	301	301	297	317	299
Near East	290	284	276	287	272	289
Asian Centrally Planned Ec.	249	281	299	321	358	364
Total Developing Countries	243	255	262	271	286	284
North America	968	1,064	1,162	1,304	1,390	1,194
Oceania	855	1,042	1,013	1,182	1,409	1,268
Western Europe	376	412	452	468	527	541
EEC	362	393	431	445	507	531
Eastern Europe and USSR	647	761	805	846	769	845
Total Developed Countries	578	650	696	746	762	747
World	348	373	384	398	408	397

Source: FAO, Policy Analysis Division.

It is generally recognized today that food self-sufficiency per se is not necessarily a desirable goal for development because of the distortions it can produce, both economically and in the use of land and other agricultural resources. Food *security*, through a combination of domestic production and trade is a more realistic goal. However, many African countries are finding it increasingly difficult to achieve even food security for their people.

Studies published by IFPRI (IFPRI 1977; Paulino 1986), covering 40 sub-Saharan African countries, show a progressively widening food gap between 1960 and 1985 for the basic food staples (cereals, roots and tubers, pulses, groundnuts, and bananas/plantains). Food consumption grew at an average of 2.5% per annum between 1961–65 and 1979–83 (table 2,) while production rose by only 1.7% per annum between 1961–65 and 1981–85 (table 3).

Consequently, there was a shortfall of nearly eight million tons by the early 1980s, leading to a net trade deficit of nearly seven million tons, compared to a trade surplus of 1.37 million tons in 1961–65 (table 4). Not only did cereal imports rise by 6.3 million tons over this period, but exports of food staples fell by 1.87 million tons. Both cereal and noncereal exports declined, but the drop in noncereal exports was much sharper. Thus, there was a progressively worsening trade balance. By the beginning of the 1980s, farmers in a number of countries were being forced by drought and other problems either to buy an increasing share of their food in urban markets or to leave their land and migrate to the cities. Between 1975–77 and 1983–85, dietary energy supplies stagnated or declined in 21 out of 38 African countries reviewed by FAO.

The food gap is not equally distributed among the subregions of Africa, nor among major food crops. In 1979–83, West Africa, with about 42% of the population of sub-Saharan Africa, accounted for 54% of all food imports. Eastern and Southern Africa, also with 42% of the population, absorbed only one-third of food imports. And Central Africa, with 16% of the population, accounted for about 13% of food imports. This reflects the very slow growth of food production in West Africa during this period, as well as the high population growth rates in Eastern and Southern Africa compared to Central Africa. Both Eastern/Southern and Central Africa had about the same annual growth rates in food production (around 2%), considerably higher than those in West Africa.

Table 2.
Average Annual Consumption of Basic Food Staples in sub-Saharan Africa, 1961-65 and 1979-83

Country/Crop/ Use Groups	1961-65 Average		1979-83 Average		Change		Ann. Growth Rate
	(mil. tons)	(%)	(mil. tons)	(%)	(mil. tons)	(%)	(%)
Sub-Saharan Africa	53.9	100.0	83.5	100.0	29.6	100.0	2.5
By region							
West Africa	25.7	48.0	37.0	44.0	11.3	38.0	2.0
Central Africa	8.6	16.0	13.4	16.0	4.8	16.0	2.5
Eastern/Southern Africa	19.6	36.0	33.1	40.0	13.4	46.0	2.9
By crop group							
Cereals	31.3	58.0	48.8	58.0	17.6	59.0	2.5
Noncereals	22.7	42.0	34.7	42.0	12.0	41.0	2.4
By domestic use							
Direct food	37.8	70.0	61.3	73.0	23.4	79.0	2.7
Animal feed	2.9	5.0	5.6	7.0	2.7	9.0	3.8
Others[a]	13.3	25.0	16.6	20.0	3.4	12.0	1.3

Source: Von Braun and Paulino (1990).
Note: Consumption here refers to total domestic utilization.
Column totals may not equal sum of columns because of rounding.
a. *Others* includes seeds, other nonfoods, and allowance for waste.

Table 3.
Average Annual Production of Major Food Crops in sub-Saharan Africa, 1961-65 and 1981-85

Country and Crop Groups	1961-65 Average		1981-85 Average		Change		Ann. Growth Rate
	(mil. tons)	(%)	(mil. tons)	(%)	(mil. tons)	(%)	(%)
Sub-Saharan Africa	56.7	100.0	79.3	100.0	22.6	100.0	1.7
By region							
West Africa	28.1	50.0	35.0	44.0	7.0	31.0	1.1
Central Africa	8.8	15.0	13.2	17.0	4.4	19.0	2.0
Eastern/Southern Africa	19.8	35.0	31.1	39.0	11.3	50.0	2.3
By crop group/crop							
Cereals	30.6	54.0	41.6	52.0	11.0	49.0	1.6
Wheat	(0.9)	(2.0)	(1.3)	(2.0)	(0.4)	(2.0)	(2.0)
Rice	(2.9)	(5.0)	(5.4)	(6.0)	(2.5)	(11.0)	(3.2)
Coarse grains	(26.8)	(47.0)	(34.9)	(44)	(8.1)	(36.0)	(1.3)
Noncereals	26.1	46.0	37.7	48.0	11.6	51.0	1.8
Roots/Tubers	(15.3)	(27.0)	(25.2)	(32.0)	(9.9)	(44.0)	(2.5)
Others	(10.8)	(19.0)	(12.5)	(16.0)	(1.7)	(7.0)	(0.7)

Source: FAO (1987).
Note: Column totals may not equal sums of columns because of rounding.

The Components of Food Supply

Because of differential rates of growth in production, there are also differences in the commodity composition of the food gap (table 3). Most of the shortfall in staple foods has been the result of lagging growth (1.3% per annum) in traditional coarse grains (such as millet, sorghum, and maize) which represented 44% of total major food crop production in 1981–85. Production of rice (3.2%

per annum) and wheat (2.0% per annum) grew faster, but their aggregate share of total food production was only about 8%. However, those two crops were the main contributors to the increase in food imports, which predominantly serve urban areas, where they represent foods of convenience for city workers. Wheat, in particular, has also been the main component of concessional and emergency food supplies.

Rather contrary to the trends in other developing regions, food crops other than cereals took an increasing share of staple food production, rising from 46% to 48% over the 1961–85 period. Most of this came from roots and tubers, whose share of noncereal food production rose from 27% to 32% (with a growth rate of 2.5% per annum), while that of other food crops (pulses, groundnuts, and bananas/plantains) fell from 19% to 16% — a growth rate of less than 1% per annum

The Contribution of Population Growth to the Food Gap

Population growth has been the primary cause of increased consumption of basic staple foods since 1970, with growth in income contributing relatively little. Whereas overall population growth has slowed down somewhat in Asia and Latin America (figure 2), in Africa it appears to be still climbing and it represents the fastest growth in any geographic region.

Table 5 shows that the number of malnourished people in Africa has risen by 52% since 1970, while the proportion of the poor in the total population has remained constant, whereas it has fallen in other developing regions. Almost one African in three was malnourished in 1983–85, broadly the same ratio as during the famine years of the early 1970s. Political upheavals have contributed to this situation, both through destabilizing agricultural production and by creating massive refugee problems in the countries directly affected as well as in neighboring countries. Meanwhile, there has been accelerated growth in the urban population, generating further demand for imports of wheat and rice.

Projections to the Year 2000

The outlook for the year 2000, shown in table 6, is alarming. Based on a projected production of 110 million metric tons of basic food staples and a demand of about 160 million tons, the deficit will rise to an estimated 51 million tons — about 6.5 times its level for 1979–83 (Von Braun and Paulino 1990). In order to close this gap, the 1.7% growth rate in food production for 1961–80 would have to more than double. This seems problematical, especially in West Africa, where rapid population growth and a particularly low growth rate in production combine to produce a massive projected shortfall of 34 million tons. However, it should be noted that these figures are based on income growth trends from 1966–1980 which may be high since they reflect the boom years of oil production in West Africa. In the light of the subsequent economic downturn there, real growth in consumption may prove to be lower.

The 1989 World Bank report (World Bank 1989) offers three scenarios for population growth and food production and consumption, extending to 2020. The outlook for the year 2000, based on a constant fertility rate and a projection of production at current 2% annual rates of growth results in a gap of 50 million tons, not too different from that in table 6, for a similar base of production (table 7). The projection to 2020 results in a horrendous deficit of 245 million tons at constant fertility levels. Even with a 4% per annum rate of growth in production, the gap would be 110 million tons. Only a concomitantly sharp decline in the fertility rate would prevent this and reduce the gap approximately to its 1980 level.

By any standards, sub-Saharan Africa faces a gargantuan task in attempting to provide food security to its future population. The outlook is complicated by uncertainties concerning future fertility rates and by four other factors affecting food production and consumption:

1. **The likely composition of future demand for food.** If cereal production fails to expand more rapidly than it has in the past, some of the deficit could be made up by increasing the output of roots, tubers, bananas, food legumes, and fruits and vegetables. Horticultural crops are not accounted for in the projections cited above and their contribution to the diet is almost certainly underestimated. However, most of these crops are bulky and perishable; they are costly to transport over long distances. Any cereal shortfall not made up by other food crops is likely to be the result of a failure in the production of

Table 4.
Average Annual Exports and Imports of Basic Food Staples in sub-Saharan Africa, 1961–65 and 1979–83

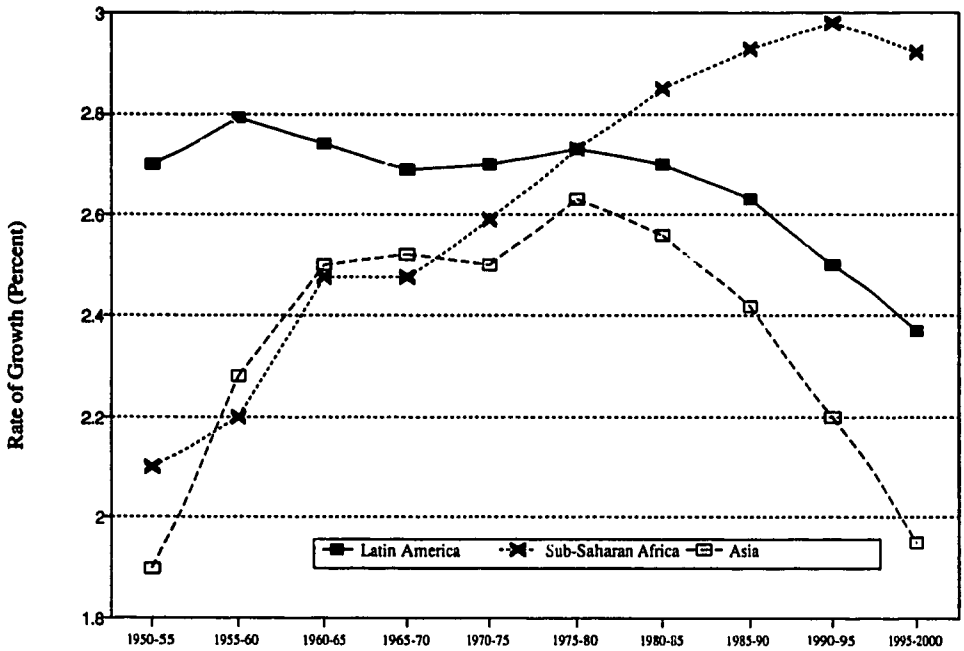
Country and Crop Groups	1961–65 Average			1979–83 Average			Annual Growth Rate		
	Exports	Imports	Net Trade	Exports	Imports	Net Trade[a]	Net Exports	Imports	Trade
	(thousand metric tons)						(percent)		
Sub-Saharan Africa	3,333	1,960	1,373	1,465	8,402	–6,937	–4.5	8.4	b
By country group									
West Africa	2,356	765	1,591	780	4,498	–3,718	–6.0	10.3	b
Central Africa	251	253	–2	66	1,111	–1,045	–7.2	8.6	c
Eastern and Southern Africa	726	942	–216	619	2,793	–2,174	–0.9	6.2	c
By crop group									
Cereals	638	1,861	–1,223	702	8,251	–7,549	0.5	8.6	c
Noncereals	2,695	99	2,596	763	151	612	–6.8	2.4	–7.7

Source: FAO (1986b).
a. Exports minus imports.
b. Change in net trade position from exporter to importer.
c. More than 10% of net imports.

Table 5.
Number and Proportion of Undernourished Population of Developing-Market Economies, by Region, 1969–71, 1979–81 and 1983–85

Region	Total Population			Number of Undernourished			Proportion of Population Undernourished		
	1969–71	1979–81	1983–85	1969–71	1979–81	1983–85	1969–71	1979–81	1983–85
	(millions)						(percent)		
Africa	286	383	432	92	110	140	32	29	32
Far East	978	1,227	1,335	281	288	291	29	24	22
Latin America	278	356	389	51	52	55	18	15	14
Near East	159	207	230	35	24	25	22	12	11
Total developing market economies (98 countries)	1,702	2,174	2,388	460	475	512	27	22	21

Source: FAO, Statistics Division.



Source: United Nations (1982).

Figure 2. Population growth rates (percent/year), 1950–2000

Table 6.
Projections of Consumption and Production of Major Food Crops in sub-Saharan Africa to the Year 2000

Country Surplus/ Group	Consumption[a]	Production[b]	Deficit
		(million tons)	
Sub-Saharan Africa	161.3	110.4	–50.9
West Africa	76.1	42.0	–34.1
Central Africa	24.4	19.2	–5.3
Eastern/Southern Africa	60.8	49.2	–11.5

Source: Paulino (1986), FAO (1987), UN (1986).
Note: Column totals may not equal sums of columns because of rounding.
a. *Consumption* means total domestic utilization, which includes direct use for food, animal feed, seeds, and other nonfood uses, and allowance for waste.
b. *Production* is based on extrapolation of country trends drawn from 1961–85 data; assumes zero growth during 1985–2000 for countries with negative trends.

sorghum and millet, the two dominant crops in the more risk-prone environments. They are not widely traded on world markets and are increasingly being replaced by wheat and rice in urban and some rural diets, even though production of those crops, especially wheat, is limited by ecological constraints to a small proportion of the arable area.

Table 7.
Population and Food Security in sub-Saharan Africa, 1990–2020

	1990	2000	2010	2020
Case I				
Population[a] (with constant fertility rate)	500	700	1,010	1,500
Food production[b] (at current-trend growth rate of 2% per year)	90	110	135	165
Food requirement[b] (for universal food security by 2020)	100	160	250	410
Food gap[b]	10	50	115	245
Case II				
Population[a] (as in Case I)	500	700	1,010	1,500
Food production[b] (at 4% annual growth)	90	135	200	300
Food requirement[b] (as in Case I)	100	160	250	410
Food gap[b] (as in Case I)	10	25	50	110
Case III				
Population[a] (with total fertility rate declining 50% to 3.3 by 2020)	500	680	890	1,110
Food production[b] (at 4% annual growth)	90	135	200	300
Food requirement[b]	100	150	220	305
Food gap[b]	10	15	20	5

Source: The World Bank (1989: 73).
a. Measured in millions.
b. Measured in millions of tons of maize equivalent.

A majority of any increasing deficit between cereal production and consumption would therefore have to be met by increased imports of wheat, rice, and maize, which could become an expanding open-ended commitment if steps are not taken to counter it.

2. **The export outlook.** In this context, the role of exports, and particularly of agricultural exports, in earning foreign exchange is crucial. Terms of trade have not favored African agricultural exports in recent years, and this, combined with crippling export taxes in some countries along with other deductions, has created major disincentives to producers. Future strategies must recognize that a strong export sector is critical to food security and exploiting comparative advantages in land use. Moreover, growth in exports stimulates growth in the economy. According to one recent study of Africa (Fosu 1990), a 10% increase in the growth of exports can independently augment economic growth by an average of slightly more than 1%.

3. **The population-pressure–poverty–land-degradation nexus.** Apart from its role in driving up the demand for food, rapid population growth puts severe pressures on agriculture's natural resource base. And this, in turn, can have negative repercussions on the capacity to produce food by increasing poverty and environmental degradation. Poverty is closely associated with environmental mismanagement. People are driven to desperation in an attempt to eke out a living for their families, and they forsake sound husbandry in pursuit of survival.

This is clear in sub-Saharan Africa. Until fairly recently, agriculture there relied heavily on an abundance of land to maintain soil fertility. Systems where the land was allowed to lie fallow for several years between relatively short periods of cropping were common. In drier areas, ruminant livestock were managed in migratory herds, moving with the rains over large areas. Population pressure on cropland, combined with balkanization and restrictions on movement across national boundaries, has limited these traditional options and generated increasing competition for land between farmers and herders. Consequently, farmers have been driven to reducing the time their land lies fal-

low, and herders have had to graze their remaining pasture more heavily without allowing adequate time for regeneration.

Arable land per capita declined significantly between 1965 and 1985 — even in land-abundant countries such as Cameroon and Tanzania. It had fallen to under 0.5 ha/capita in Uganda, Malawi and Rwanda by 1989. Table 8 shows how arable land per capita is expected to fall over the present decade to levels equivalent to those in South Asia today – 0.48 in Nigeria, 0.45 in Malawi, and 0.39 in Kenya. This suggests that there are major problems facing farmers' attempts to bring new land into cultivation.

The highlands of sub-Saharan Africa contain only about 50 million people, and two-thirds of the African population is concentrated in non-highland areas. But there are almost three times more people per square kilometer in the two most densely populated highland ecozones than in the two most densely populated lowland ecozones (figures 3 and 4). FAO (1982) estimated that *by 1975* a majority of the countries in both the drier areas of the East African highlands and the "Sahelian Zone" had already exceeded the population that their land resources could support with domestic food production at traditional input levels, with almost no use of fertilizer.

Recent work at IFPRI (Broca and Oram 1991) shows that there is a high incidence of poverty and malnutrition associated with the high population concentrations in the East African highlands (table 9). There is also evidence of devastating environmental degradation, epitomized by the tragedy in Ethiopia. In the vast semi-arid and arid zone stretching across Africa from the Atlantic coast to the Indian Ocean there is also a high incidence of poverty (40%-55%). The population in that area is 113 million.

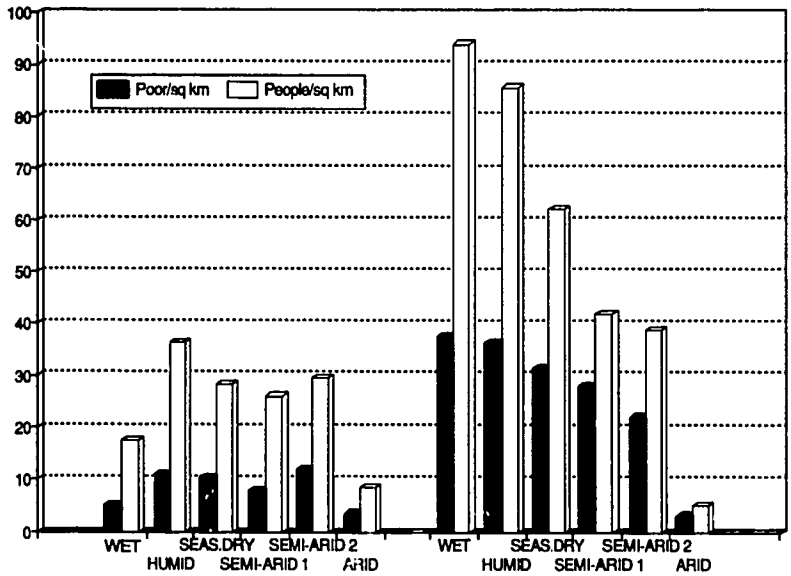
This is the region of Africa that has the highest risk of severe and prolonged drought. Drought has become cumulative and self-perpetuating here as the environment has deteriorated and soils have lost structure and fertility with successive years of dry weather. This region also contains a high proportion of land-locked countries, generally with very poor internal communications — causing difficulties with famine relief (figure 5).

It is noteworthy that with increasing aridity, the population-carrying capacity of the land *declines* progressively, and there is also a progres-

Table 8.
Per Capita Arable Land in Selected Countries (Hectares per Person)

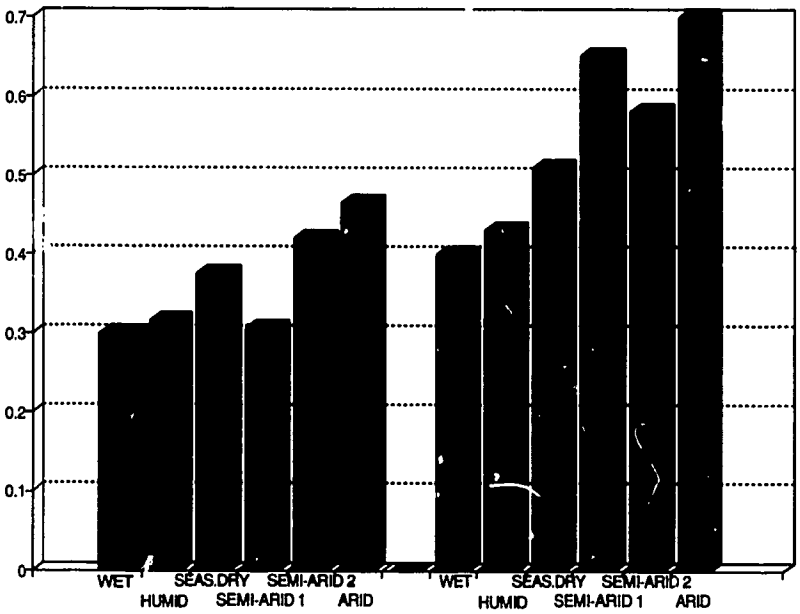
	1965 Population	1985 Population		2000 Population	
Country	Total	Rural	Total	Rural	Total
East Africa					
Kenya	1.34	0.89	0.73	0.56	0.39
Malawi	1.31	0.84	0.73	0.60	0.45
Tanzania	3.99	2.67	2.30	1.96	1.44
West Africa					
Cameroon	5.99	5.40	3.45	4.18	2.09
Nigeria	1.22	1.01	0.71	0.88	0.48
Senegal	2.67	2.41	1.62	1.76	1.04

Source: Lele (1989).
Note: Arable land: estimates and methodologies vary; for Kenya, which conducted a detailed agroclimatic analysis in conjunction with the German Agency for Technical Cooperation (GTZ), the estimate is 26%. For other countries, such as Cameroon and Nigeria, where extensive soil analysis is lacking, the estimates reach 75% of total land area.
Population: Figures are projected from the most recent census in each country to the years 1985 and 2000. Rural population is calculated from government estimates of urban population and percent urbanized in the year 2000.



Source: Broca and Oram (1991).

Figure 3. Population density and poverty density for sample of sub-Saharan countries



Source: Broca and Oram (1991).

Figure 4. Proportion of population in poverty by agroecological zone, estimates for thirty-three countries in sub-Saharan Africa

sive *increase* in the proportion of the population in poverty.

Nevertheless the capacity of a region or country to support its population is not immutable but can vary according to the way the resource base

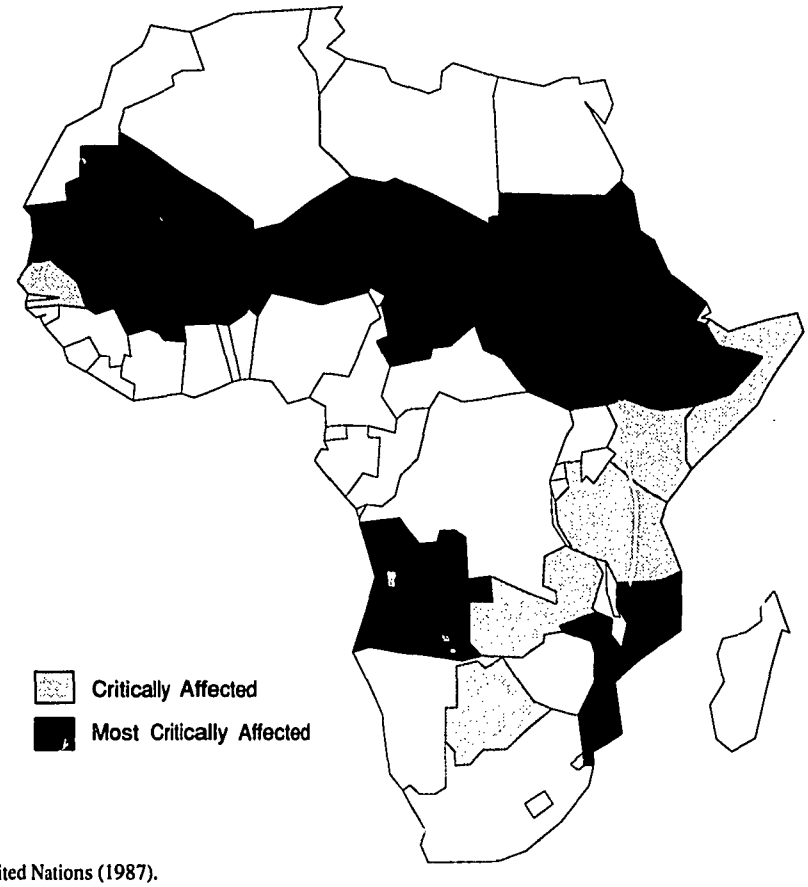
Table 9.
Estimates of Total Population in Poverty in a Sample of Thirty-Three sub-Saharan African Countries, by Agroecological Zone (in Thousands)

		Warm Tropics						Tropics Modified by Altitude					
Growing Period (Days/Yr):		(330–365)	(270–329)	(210–269)	(150–209)	(90–149)	(0–89)	(330–365)	(270–329)	(210–269)	(150–209)	(90–149)	(0–89)
Agroecological Zone:	Total	Wet	Humid	Seas.Dry	Semi-Arid1	Semi-Arid2	Arid	Wet	Humid	Seas.Dry	Semi-Arid1	Semi-Arid2	Arid
Total population for sub-Saharan Africa	420,681	38,096	67,419	64,935	87,674	56,752	56,303	1,651	7,003	19,192	10,911	5,671	5,220
Percentage	100.0	9.1	16.0	15.4	20.8	13.5	13.4	0.4	1.7	4.6	2.6	1.3	1.2
Total area (000 km^2) for sub-Saharan Africa	22,398	2,154	2,002	2,628	3,880	2,085	7,406	19	94	344	224	158	1,303
Percentage	100.0	9.6	8.9	11.7	17.3	9.3	33.1	0.1	0.4	1.5	1.0	0.7	5.8
Number of people per km^2 for sub-Saharan Africa	19	18	34	25	23	27	8	89	74	56	49	36	4
Total population for sample of countries	367,810	34,257	62,524	50,324	76,487	49,573	53,776	1,403	6,136	16,461	7,932	4,840	4,097
Percentage	100.0	9.3	17.0	13.7	20.8	13.5	14.6	0.4	1.7	4.5	2.2	1.3	1.1
Total population in poverty for sample countries	140,189	10,320	19,759	18,798	23,406	20,724	24,838	564	2,604	8,364	5,152	2,788	2,872
Percentage	100.0	7.4	14.1	13.4	16.7	14.8	17.7	0.4	1.9	6.0	3.7	2.0	2.0
Percentage of sample population in poverty	38.1	30.1	31.6	37.4	30.6	41.8	46.2	40.2	42.4	50.8	65.0	57.6	70.1
Total area (000 km^2) for sample countries	18,705	2,064	1,749	1,802	2,973	1,685	6,789	15	71	263	188	127	922
Percentage	100.0	11.0	9.3	9.6	15.9	9.0	36.3	0.1	0.4	1.4	1.0	0.7	4.9
Number of people per km^2 in sample countries	20	17	36	28	26	29	8	93	86	62	42	38	4
Number of poor people per km^2 in sample countries	7	5	11	10	8	12	4	37	36	32	27	22	3

Source: Broca and Oram (1991).

The Countries in the sample:

Benin	Central African Rep.	Gabon	Ivory Coast	Mauritania	Sierra Leone	Zaire
Botswana	Chad	Gambia	Kenya	Niger	Somalia	Zambia
Burkina Faso	Congo	Ghana	Liberia	Nigeria	Sudan	Zimbabwe
Burundi	Equatorial Guinea	Guinea	Malawi	Rwanda	Tanzania	
Cameroon	Ethiopia	Guinea-Bissau	Mali	Senegal	Togo	



Source: United Nations (1987).

Figure 5. Areas most critically affected by drought in Africa, mid-1980s

is utilized — a priority goal for agricultural development must be to improve the management of natural resources.

4. **The threat of global warming.** Farming in Africa will remain predominantly rain-fed for the foreseeable future, exposing farmers to continuing climatic insecurity from unpredictable periods of drought, which may be exacerbated by the greenhouse effect. The jury is still out on the issue of global warming, although some climatologists believe that West Africa is already the first geographic region to experience a climatic change of any duration since the little ice age of the Middle Ages.

Be that as it may, there is no certainty that global warming would lead to even greater climatic stress in Africa, although it is likely to increase instability in the shorter term. As some recent attempts to map the future distribution of climate show, there are much larger areas of uncertainty concerning precipitation than temperature. In addition, the effect of increased CO_2 on plant growth in open fields is difficult to determine empirically. Clearly it is essential to monitor climatic phenomena more carefully, both globally and regionally, and not to treat weather as a constant as planners have tended to do in the past. This is a matter for international cooperation, as well as for long-range contingency planning related to food security at the national level.

Grounds for Hope

In fact there has been some alleviation of the drought in Africa during the late 1980s, although

over the decade as a whole, bad and good years occurred in different regions of Africa with no obvious pattern. Some good years have seen exceptional harvests, even embarrassing short-term gluts of food, suggesting that gradual technological change *is* occurring, even if not very perceptibly. This offers grounds for hope, especially if conditions for trade between countries able to produce a surplus and those in deficit can be liberalized.

More notably, there appears to have been a change in political attitudes, with a realization on the part of African governments (perhaps with the Asian experience in mind) that with over 70% of the population still in agriculture, the sector merits a higher priority as the potential engine of growth for their economies. This has been reflected in a greater willingness to undertake measures for structural adjustment and to adopt more realistic exchange rates and less draconian policies for taxing agricultural exports. According to a recent report (USAID 1989), 28 African countries have taken steps towards structural adjustment during the 1980s and several have improved their standing with respect to several economic indicators during 1985–87 compared to 1980–84 (table 10). This is encouraging, but it must be borne in mind that the latter period was one of above-average weather whereas there was a serious drought affecting much of Africa between 1982 and 1985. Moreover, there are social costs related to structural adjustment which are not always reflected by economic indicators.

Progress towards Food Security in Africa — Achievements and Constraints

Sources of Growth in Agricultural Production

Land area expansion. In most developing countries, the past growth of agricultural production has relied heavily on expanding cultivation of new land areas. Land and human labor were the principal

Table 10.
Summary of Economic Performance Indicators (Average Annual Growth Rate Unless Otherwise Noted)

		All Countries	
Indicator	Period	Strong Reform Programs	Weak or No Reform Programs
Growth of GDP (constant 1980 prices)	1980-84	1.4	1.1
	1985-87	2.8	2.6
Agricultural production	1980-84	1.1	1.3
	1985-87	2.6	1.5
Growth of export volume	1980-84	–1.3	–3.1
	1985-87	4.2	0.2
Growth of import volume, excluding oil exporters	1985-87	1.7	–2.7
	1985-87	4.8	—
Growth of real domestic investment	1980-84	–8.1	–3.7
	1985-87	–0.9	–7.0
Gross domestic savings (as percentage of GDP)	1982-84	9.9	2.3
	1986-87	10.7	6.0
Growth of per capita consumption (real)	1980-84	–2.3	–1.1
	1985-87	–0.4	–0.5

Source: IBRD (1989).

sources of growth through the 1950s and 1960s in South and Southeast Asia, the Near East, and Latin America, as well as in Africa. The contribution of technological change was limited.

Over time this situation has changed significantly. Increasing population pressure on land has reduced the average farm size in areas already cultivated, and in some important areas — particularly in South and East Asia, West Asia and North Africa, and Central America — there is virtually no new land left for exploitation, even in remote areas. Thus, the emphasis has shifted to raising productivity on existing land through investment in soil improvement, irrigation, and infrastructure, and through technological change.

This transition has been slow in Africa. Irrigated land still represents only 3% of the arable and permanent crop area, despite an increase of about 1.2 million ha (30%) since 1977. Technological change has so far had only limited impact. Consequently, expansion of land area, although slowing down (growth between 1977 and 1987 averaged only 0.5% per annum) has remained the principal source of growth of production — especially for food crops. This decline seems paradoxical in a region with only 60% of its arable area under cultivation in any one year and where food imports are escalating. However, as Matlon (1987) has pointed out, this is a misleading statistic for several reasons:

1. Large areas are unsuitable for agriculture because of desert, rock outcrops, and in East Africa, steep slopes. While population per square kilometer of *total area* in Africa appears low, population density per square kilometer of *arable land* is as high in Africa as it is in Southeast Asia (table 11).

2. Soils vary widely in quality over relatively small areas, and the better soils are usually already under cultivation. Thus, any extension of cropped areas often involves a decline in productivity and lower returns to labor unless some new technology is involved.

3. Because of interactions between the climate and soil, as well as the low inherent fertility of many African soils, it is often impossible to maintain cultivation for more than two or three years under traditional methods of husbandry without a fallow period. The ratio of fallow to crop years under this system is five to one or higher. This fallow period is being progressively shortened under population pressure, leading to a decline in the area of forest and to degradation of soil fertility.

Table 11.
Summary of Aggregate Data on Population and Population in Poverty in Relation to Total Land Area and Agricultural Area for sub-Saharan Africa, South Asia, and Southeast Asia

Region	Total Population	Total No. of poor	Share of poor in Total Pop.	Total Land Area	Population Density	Poverty Density
	(millions)	(millions)	(percent)	(000 km^2)	(people/km^2)	(poor/km^2)
Sub-Saharan Africa	368	117	31.7	18,705	20	6
South Asia	842	294	34.9	4,295	196	69
Southeast Asia	240	71	29.7	2,733	88	26
Total	1,450	482	33.2	25,733	56	19

Region	Total Agric. Area	Arable Area	Population to Agric. Area	Poverty to Agric. Area	Agric. Population	Urban Population
	(000 km^2)	(percent)	(people/km^2)	(poor/km^2)	(% of total)	(% of total)
Sub-Saharan Africa	1,262	6.7	291	93	72	12
South Asia	2,021	57.3	416	145	71	15
Southeast Asia	461	16.9	296	154	57	12
Total	3,744	14.5	387	129	69	14

Source: Broca and Oram (1990).

4. The distribution of the rural population is not always consonant with agricultural potential. Some relatively fertile areas are underpopulated because of river blindness, tsetse flies, malaria, and excessive humidity, while other areas of lower potential are more densely settled because of historical patterns of ownership, or for security against enemies. Disease (including AIDS, as a new and worrying addition to the problems mentioned above) seriously detracts from labor productivity. Tsetse flies are the vector of trypanosomiasis. If they could be controlled effectively, or if a vaccine could be developed against the disease, it would be possible to open up an area land as large as the United States — relatively fertile and well watered — for settled farming of crops and livestock. It would also enable draft animals to be kept on farms, thus alleviating labor bottlenecks.

5. The prevailing system of husbandry on the family farms that predominate in most of West Africa is based on human labor and the hoe, limiting the area that can be cropped each year to about three hectares. Oxen or cattle are used fairly widely in semi-arid francophone Africa, in northern Nigeria, and in East Africa. In these areas, farming systems incorporating bovines for work and milk tend to be more productive than those dependent only on annual crops, and they have higher net incomes. Yet one survey shows that the number of cattle-owning households is declining, apparently due to competition between crops and animals for land, which is reducing the availability of grazing areas (Collinson 1987).

6. Tractor-based mechanization of small farms along Western lines has not proved economically feasible in Africa, and although a number of state-run schemes along these lines have been launched, most have eventually foundered due to poor management, incompetent maintenance, and high costs of operation.

7. Population pressures lead to soil erosion and degradation, resulting in land actually going out of production. Even where this is not the case, land productivity is often declining, so the net effect is the equivalent of land being lost. FAO (1982) states that where no measures have been taken to check soil erosion in Africa, there has been a long-term net decrease in rain-fed cropland of 16.5%, and a decrease in crop productivity of 29.4%.

8. Labor bottlenecks and shorter fallow periods are leading to a serious build-up of weeds. This not only reduces crop yields, but in some cases, particularly with parasitic weeds, it may prevent the cultivation of key crops for an indefinite period. Striga, which is parasitic on maize, millet, and sorghum, is the most serious problem, but alectra, which attacks cowpeas, is also important.

9. "New" land is being brought into cultivation at the expense of forest and range areas. Although statistics on those areas are notoriously ambiguous because of the difficulty of assessing the quality of the resources defined, it appears that over the decade 1977–87, the African "forests" declined by 26 million ha (4%) and "permanent pastures" declined by 5 million ha (0.8%). The aggregate decrease of 31 million ha is more than four times the recorded *increase* in the area of arable land and that under permanent crops over the same period. It is not clear what has happened to these "lost" resources, but any short-term gains in arable area at the expense of the sustainability of other natural resources are likely to prove illusory.

For these reasons only a slow expansion of the total cultivated area is foreseen in the current decade, perhaps around 1% per year. Anything more radical would require major changes in the traditional structure of farming and patterns of group land ownership, including greater privatization and probably consolidation of holdings to facilitate mechanization. While there are some indications of shifts towards individual ownership, especially in the East African highlands, there are accompanying signs of fragmentation due to inheritance.

The contribution of irrigation. Sub-Saharan Africa has about 5.3 million ha of irrigated land, a smaller amount (both absolutely and in proportion to its total area) than any other major geographical region. The area irrigated has expanded at about 1% a year over the past 15 years: the share of total arable and permanently cropped areas with some sort of supplemental water supply has risen from 2.5% to 3.4%.

Irrigation with good water control not only reduces the risk of crop loss from dry weather, but by reducing those risks, it also provides incentives to more intensive husbandry; the use of high-yielding varieties, fertilizer and other yield-increasing inputs; and the production of more crops per unit of time and labor as well as per unit of land. Thus, it is disappointing that irrigation has contributed so little to increasing food production in Africa.

One reason for this is that land defined as irrigated in Africa is often not part of a modern system with a reliable supply and effective delivery, permitting good water control. There are exceptions such as the Gezira scheme in the Sudan, some new projects in northern Nigeria, and several smaller river-based schemes in Eastern and Southern Africa, sometimes under commercial management for sugar cane production. However in other countries, such as Madagascar, there are large areas with very poor water control.

Groundwater development, which has been so productive in much of South Asia, has not been exploited much in Africa, except in the form of shallow wells. Tube-well development is very rare.

There are a number of reasons for this, but apparently the main one is not a lack of potential. The FAO (1986a) reports that there are approximately 34 million hectares of irrigable soils in sub-Saharan Africa; this is equivalent to about 26% of the current agricultural area there. Unfortunately, seasonal river flows are unreliable, requiring dams to assure good water control for intensive agriculture, and the terrain does not lend itself well to dam sites. Another assessment by CILSS (1980), foresees an irrigation potential of 2.3 million ha to be developed early in the 21st century. This coincides approximately with a 1981 USAID projection, both being based primarily on dam projects. These seem likely to be very costly, ranging from $5,000/ha for small projects to $25,000/ha for large-scale projects; a problem also indicated by CILSS estimates of the costs and benefits of developing the groundwater potential in the Sahel.

Certainly the difficulties of engineering and command area development seem likely to be formidable. But they should not be any more formidable than those of on-farm development and water use by a farm population with almost no experience with irrigated agriculture (or with maintenance of the systems, which has often proved the nemesis of irrigation projects in regions with greater experience in project management than that of sub-Saharan Africa). According to Matlon (1987), yields in existing projects in West Africa are not markedly superior to those of rain-fed farming, due to poor water control, the absence of double cropping, inadequate input supply, and unsuitable agronomic packages. Poor soils may be a further reason. Collinson (1987) states that because high absorption of water by soils limits the availability of water in the aquifers, irrigation is not a promising strategy for agriculture in Eastern and Southern Africa.

While irrigation may be an arguable proposition for the long run, it seems unlikely that new irrigation projects will make a large incremental contribution to food security by the end of this century. What could be of more importance would be to upgrade some existing irrigation facilities and to improve water control and production practices in the numerous small basins with hydromorphic soils, which FAO assesses at around 80 million ha in Africa overall and which are suited to labor-intensive cropping systems with rice, vegetables, bananas, and other crops. Progress along those lines could be rapid once the resource potential has been more thoroughly surveyed.

The contribution of fertilizer. By raising output per unit area, fertilizer and animal manure are proxies for land area expansion; they may also contribute to reducing erosion and thus saving land by helping to build up soil fertility and structure and improving its water-holding capacity.

Unfortunately, but for different reasons, neither fertilizer nor manure is being widely used by African farmers. Oram (1988) reports that only 13 out 38 African countries for which data were available used more than 10 kg N-P-K fertilizer per hectare of arable land, and only five countries used over 20 kg/ha. Total fertilizer use was about 1 million tons by the mid-1980s. It is mainly used on cash crops, and very little is applied to staple food crops. Moreover, the growth rates of fertilizer use have declined progressively from 11.5% annually in the 1960s, to 6.0% in the 1970s and 4.3% in the 1980s (Tshibaka 1990).

Africa represents only 2.25% of the *developing* world's fertilizer consumption. This is a matter of serious concern in a region where many soils are extremely low in the major nutrient elements and where micronutrient deficiencies are being identi-

fied on an increasing scale. FAO estimates that a sixfold increase in fertilizer use to 6 million tons would be needed in Africa between 1979–81 and 2010 to raise agricultural production by 2.9% per year.

Data on the average amount of animal manure used are not published, but as many farms — especially in the wetter, tsetse-infested areas — keep no ruminant animals, and many of the animals that are kept in the Sahel are on the range for much of the time, animal manure is not always available. Even where animal manure is available, it may be used for fuel rather than for improving soil fertility. Alternatives such as green manure are not popular because they compete with food and cash crops for land and labor, although food legumes and forage contribute nitrogen when grown with other annual crops. Alley cropping based on leguminous trees shows promise for maintaining annual crop yields without a long fallow period in the intermediate rainfall zones of the humid tropics where soils are not acid. But it is not so promising in the very wet areas. It is a labor-intensive system, and there is a need for further farm-level testing to determine its acceptance.

Exploratory research at IFPRI indicates that a number of factors have contributed to the slow expansion of fertilizer use and its lagging growth in recent years (Desai and Gandhi 1990). These include the following:

- falling prices for the export crops on which most of the fertilizer has been used;
- slow diffusion of fertilizer use on food crops, constrained by the absence of major breakthroughs in fertilizer-responsive varieties;
- retrenchment by governments in fertilizer imports because of their debt burden;
- a mixture of other factors affecting supply and demand.

Technological change, yield growth, and input use. The declining contribution of area expansion to the growth of agricultural production places a heavy burden on other sources of growth to achieve the overall 4% growth rate required to avoid burgeoning food deficits and balance-of-payment difficulties. Even this target, which seems extremely optimistic if not unattainable, assumes a substantial complementary reduction in the rate of population growth. In areas of reasonably reliable rainfall, land-use intensities may show some increase over the longer term by exploiting two sources of growth: expanding irrigated areas and using mechanization to facilitate double-cropping and land-use diversification. However, the short-term potential from either of these appears to be limited.

The main onus must therefore rest with technological change, which so far has contributed rather less to the growth of food production than has area expansion. Data for the four key African cereals show growth rates averaging only around 1% or less for 1960–70, and in several cases they show negative growth after 1970–1982. Only wheat in East Africa exceeded an annual growth rate of 2%, as shown in table 12.

In order to approximate the growth rates required for food security, productivity per hectare and/or per unit of time must be raised around 2% above current average growth rates in yield. This means a total growth rate of about 3% per annum for productivity, plus an increase of 1% in the expansion of cultivated areas, in order to achieve the overall 4% growth rate required.

Lessons from the past. In looking at the potential for such an increase and the strategy required to achieve it, it is illuminating to look at past progress

Table 12.
Average Annual Percentage Change in Yield per Hectare of Cereals, 1960–1982

	Period	Maize	Rice	Millet	Sorghum	Wheat
E. Africa	1960–70	0.96	1.11	1.11	0.68	2.28
	1970–82	–0.88	–1.13	–1.68	0.74	2.28
W. Africa	1960–70	1.76	0.15	0.41	–2.73	1.10
	1970–82	–0.59	0.50	–0.11	–0.16	1.03

Source: World Bank (1983).

in the generation of improved agricultural technology in Africa and its adoption by producers.

Eicher (1989) has cited successful research on oil palm and rice in Zaire, cocoa in Ghana, hybrid maize in Zimbabwe and Kenya, and cotton in francophone West Africa as examples of significant progress by relatively small teams of scientists working in an environment where continuity was possible. Some of those programs have generated research that has been beneficial not only to the country where it was undertaken, but also to other countries in Africa and elsewhere.

A majority of that work was initiated in colonial days, and some of the national stations involved have since suffered disruptions from the departure of expatriates; a shortage of local scientists; low or inconsistent government support; lack of foreign exchange for purchase of equipment, chemicals, vehicles, and upkeep; and frequent changes in management.

The transition from colonialism to independence is inevitably difficult and it has taken many years to build viable national research and extension systems. Past experience in Africa and with the Green Revolution in Asia offers five valuable lessons:

1. Interdisciplinary critical mass is vital to success, but above the level needed to attain this, sheer numbers of researchers are not as necessary as conceptual ability, good leadership, and sound training.

2. Continuity of staff, financial stability, and long-term moral support from government are essential ingredients of success.

3. Funding must be geared closely to managerial capability and absorptive capacity. Neither more staff nor more money is a guarantee of success.

4. Concentration of effort on a few priority commodities or problem areas, with well-defined objectives has proved a key to success.

5. Provided a country has a sound adaptive research capability, borrowing technology derived from research in other countries or international centers is a legitimate strategy for accelerating progress, and it may be the main hope for smaller countries with limited scope for producing new technology through basic or applied research. However, the demands that this makes on the experience and ability of researchers should not to be underestimated.

These lessons have been long in taking root in Africa; progress by NARS in developing new technology for food production and transferring it to farmers has been slow and limited in scope. This is in spite of the establishment of the CGIAR in 1971, which was created to support ongoing and new international agricultural research centers (IARCs) and other research initiatives. Eicher's (1989) view is that the CGIAR and the French networks have not yet delivered the volume of new food production technology that many experts had implicitly promised when the CGIAR's first African center — IITA — was established at Ibadan some 20 years ago.

It is certainly true that the so-called Green Revolution has had virtually no impact in Africa. But quite apart from the other constraints to its success there (discussed in the introduction, above), the two crops on which its impressive successes were built in Asia, wheat and rice, and which have been well researched worldwide, are of relatively marginal importance to food production in most African countries. Ecological conditions in Africa are unfavorable to their large-scale production — especially of wheat.

Despite early successes in developing hybrid and composite maize varieties in Eastern and Southern Africa, progress in increasing maize yields there has been uneven, although there are indications of improved performance in the 1980s, as well as of a general expansion of the area planted to maize in Africa. This seems also to be true of rice, particularly in West Africa. Most other African staples (millet, sorghum, cassava, yams, cowpeas, bananas and plantains, and traditional vegetables) have received little attention from advanced research institutions elsewhere.

Thus, the IARCs in Africa have had to start almost from scratch. Moreover, they are best equipped to develop new components of agricultural technology, which have to be tested under local conditions, adapted, and incorporated into production technology within farming systems by national researchers. Until very recently, NARS were extremely weak in this respect.

Thus, there has been a substantial learning experience involving the management and staff of the IARCs, their putative partners in the NARS, the governments and donors of the region, the extension workers, and the farmers. Although this has had substantial benefits in building knowledge and developing human resources, it has extended the time lags normally required for the generation and transfer of new technology to farmers, while other factors beyond the control of IARCs and the NARS have impeded the adoption of technology. This in itself is a subject requiring more research, and progress in developing acceptable technology might have been faster had the factors affecting farmers' decisions been better understood by researchers — and also if the lessons had been applied in planning their programs. This may have been an example of "more haste, less speed"!

Current availability of suitable technology. There have been several recent reviews of the farming situation in Africa, the problems facing the improvement of agricultural productivity and the attempts that are being made to find solutions through research and extension (see Mellor, Delgado, and Blackie 1987; Oram 1988; Carr 1989; Tshikala Tshibaka and Delgado 1990).

These reviews are helpful in answering the vexing question, "Is there off-the-shelf agricultural technology available for use in Africa?" Briefly, the answer is, "Yes." But some of it is only suited to larger farms, and some should remain on the shelf until changes in labor availability, input supply, infrastructure, or other current constraints create a demand for it. Only a limited quantity could be immediately applicable, even with modifications to suit local conditions. The following broad conclusions can be drawn:

1. There is no Green Revolution with "miracle seeds" on the horizon, but there *is* improved genetic material for a range of ecological situations, e.g., with maize, cowpeas, soybeans, cassava, yams, and recently, with sorghum. This offers better pest, disease, and stress resistance, leading to lower risks and greater yield stability.

2. There is substantial evidence that food crops respond very favorably to fertilizer applications.

3. There are important benefits to be gained from improved agronomic practices, especially properly timed planting and weeding.

4. Seed treatment is proving a low-cost means of achieving modest gains in yield.

5. Measures such as tie-ridging and the use of embankments to control erosion and reduce runoff can have a high payoff, but they are labor-intensive.

6. Closer crop/livestock integration is one way to mitigate land constraints in areas of low population density. It can also facilitate intensification where land is scarce. In addition to work output, cattle provide additional benefits in terms of milk, manure, and consumption of farm by-products.

7. Successful development of the staple food sector through technological change and growth in the cash-crop sector are complementary. Appropriate policies for input supply, output marketing, and infrastructure are of benefit to both sectors and are crucial for growth.

8. There are wide gaps between the potential yields obtained in controlled trials on experiment stations, those from on-farm trials, and farmers' own yields. Collinson (1987) compares experimental maize yields of 15 ton/ha and potential commercial expectations of 8.5 ton/ha, although average farm yields of maize in East Africa vary from only 0.6 ton/ha to 2 ton/ha (table 13). ICRISAT (1990) has estimated a yield gap of 60% between experimental yields and farm yields. Considerable progress may therefore be possible through the adaptation of genetic material to local situations along with improved agronomic practices, through research, extension, and farmer cooperation.

9. The achievement of farm yields much closer to experimental potentials is unlikely to result from any single piece of technology in isolation, but it will require an additive approach that builds on the complementarities of the two systems (table 14). While this does not mean that progress in raising productivity will not be feasible without applying the whole package, it does imply a need to consider each item as a component of a technology rather than as a stand-alone measure.

Table 13.
Actual and Potential Yields for Livestock and Major Crops in Ethiopia, Kenya, Tanzania, and Zambia

Product	Ethiopia	Kenya	Tanzania	Zambia	Potential Commercial Yield in Highlands
Crop (quintals per hectare)					
Sorghum	9.00	10.50	6.30	5.00	50.00
Maize	10.00	18.57[a]	5.77	8.70	35.00—85.00
Wheat	9.40	17.70[a]	14.00[a]	47.27[a]	60.00
Cassava	—	79.00	49.00	31.00	250.00
Irish potatoes	60.00	76.00[a]	56.00	—	400.00
Sweet potatoes	—	88.00	62.00	71.00	125.00—175.00
Pulses	7.35	4.36	4.34	9.33[a]	20.00
Groundnuts	5.26	5.71	5.96	6.00	—
Livestock					
Milk (quintals per head)	2.30	4.47[a]	3.25	3.00	20.00
Beef (quintals per dressed carcass)	1.09	1.30	1.01	1.60	5.00

Source: Acland (1971) and Collinson (1987).
a. Includes significant large-scale commercial production.

Despite these relatively optimistic conclusions, the picture presented by the *actual* levels of technology use found among small farmers in Africa is extremely discouraging.

In a comprehensive review of technology for small-scale farmers in sub-Saharan Africa, covering the five major agroecological zones, Carr (1989) examines 25 World Bank projects aimed at introducing improved technologies. The difficulties experienced in persuading farmers to adopt many of the proposed innovations, even where they appeared promising and relevant to the project planners, resulted in a depressingly high incidence of failure in achieving the project objectives. Reports from other donor agencies paint a similar picture.

Several important conclusions can be drawn from Carr's analysis:

1. The technologies available to overcome farmers' most pressing constraints (e.g., tractors to increase the area cultivated) may often be inapplicable or impractical for smallholders because of economic or financial reasons. *It is therefore essential to distinguish the availability of technology from its applicability and economic feasibility.*

2. This applies not only to purchased inputs, but also to simple agronomic improvements, such as timely cultivation, planting, and weeding, which may be impeded by labor bottlenecks at critical points in the farming year. Labor constraints seem to be a major reason for low levels of technology adoption in much of Africa.

3. The value of a technology to a farm family or community may change over time, either rendering it unattractive or, conversely, opening the way to its use. Timing is therefore critical to the successful adoption of innovations.

4. The African agricultural scene is extremely complex. Frequent contacts between research and extension staff and farmers are needed so that farmers' constraints may be understood and the technology can be tailored to priority crops and location-specific needs.

5. Varietal improvement, which has been the keystone of success in raising productivity elsewhere, has not yet paid high dividends in most of Africa. Promising new varieties are often rejected by farmers because they fail to meet a criterion not foreseen by the breeders, or whose importance was underestimated.

Table 14.
A Summary of Innovations in Maize Growing and Their Impact on Yield

Component	Content	Yield (kg/ha)
Basic	Traditional variety, low fertility, one weeding	600
Improved variety	Use of improved seed with small increase in plant population	700
Improved fertility	Application of 40 kg N/ha and 15 kg P/ha	1,100
Time of planting	Time of planting moved nearer to optimum for the area	1,300
Weeding	A second weeding	1,400
Plant population	Plant population increased from 25,000/ha to 35,000/ha	1,500
Further improvement to fertility	Fertilizer increased by an additional 50 kg N/ha and 20 kg P/ha	2,100
Change to hybrid seed with improved timing of operations	Use of suitable hybrid planted within two weeks of start of rains and weeded within one month of planting	2,800
Improved pest control	Appropriate action to control stem borers and other pests	2,950
Additional improvement to fertility	Addition of 50 kg N/ha and 30 kg P/ha	4,000

Source: CARR (1989).

6. Input pricing is a cause for concern. Even large yield increases may be unremunerative because of high input costs — especially of fertilizer.

7. Even where seed is the main input required, farmers are not always willing to adopt new varieties because seed production may not be reliable and the seed may not be available at the right time, in sufficient quantity, or at a reasonable price.

8. The nemesis of many otherwise promising technical innovations has been that farmers were inhibited from adopting them by factors largely outside their control rather than by their own conservatism. There is a consensus in the various reviews cited above that African farmers are not reluctant to innovate when they can see clear economic benefits from a new variety or technology. The most commonly cited obstacles outside their control are price, fiscal, and exchange rate policies that do not favor agricultural producers; lack of availability of inputs or high delivery costs; market constraints; and shortages of cash or credit.

Most agricultural chemicals have to be imported and shipped long distances from ports to distribution points. Thus, herbicides or seed dressings, which are less bulky than fertilizer, may theoretically offer better benefit-cost ratios.

However, yields are often so constrained by low soil fertility, especially in West Africa, that returns to other inputs are low, which raises the issue of subsidies with respect to selected inputs, particularly fertilizer.

Carr (1989) points out that there are few areas in the savannah zone of Eastern and Southern Africa where maize would yield a 2:1 benefit-cost ratio to fertilizer at undistorted input and output prices. Attempts to introduce a maize credit package to Zambia have run into difficulties for this reason, as a result of structural adjustment. Similar reports from West Africa suggest that this may be a principal reason for the decrease in fertilizer use discussed earlier in this paper.

Thus, the problem may involve not only unsuitable technology, but also inappropriate policies. This puts a premium on food-security policy research and implies that a closer dialogue than is usually the case at present is needed between the following two groups: (a) policymakers and their advisors and (b) research and extension managers.

One broad conclusion is that there is now a better understanding of what needs to be done to develop more acceptable technology for African farmers, with more realistic goals based on that understanding. However, the *acceptance* of currently available technology for most staple food crops has been low — even the encouraging adoption of hybrid and composite maize varieties in Kenya, Zimbabwe, and Malawi has not been replicated in other areas in Africa.

Although there are differences in average *levels* of yield for a given crop among different countries, the *growth rate* of yields has often been no better in high-potential areas than in areas of lower potential.

While there are pan-African needs, such as improving labor productivity and raising environmental sustainability, and there are pan-African commodity priorities, there are no pan-African solutions.

Near-term progress in research will depend on improving the understanding of farmers' needs and constraints, as well as on matching technologies more closely to farmers' situations. This requires strong research-extension-farmer linkages. And while this may seem an unambitious, unspectacular, and human-resource–intensive recipe, the history of attempts to find quick technical fixes to the problems of Africa is replete with failure.

In the next section we will discuss some of the policy implications for investment in institutions concerned with the development and transfer of new technology.

2

Agricultural Research and the Capacity for Technology Transfer

The Expansion of Research Capability in Africa Since the 1960s

During the 1960s and early 1970s, agricultural research in Africa was at a low ebb. In particular, the problems of food production were receiving insufficient attention. In 1960–64 there were only about 1100 researchers for all sub-Saharan countries, and total research expenditure was around US$120 million in constant 1980 dollar terms.

Since then there has been a remarkable transformation. According to Jain (1990), by 1985 numbers of researchers in national systems had more than quadrupled to 4870 (apparently this number excludes 2790 agricultural scientists at university faculties), and funding had increased to approximately US$382 million in 1980 dollars (tables 15 and 16).

In addition there has been considerable strengthening of the international agricultural research effort directed at finding solutions to Africa's problems. The year 1971 saw the establishment of the CGIAR and the opening of its first African-based institute, the International Institute of Tropical Agriculture (IITA), in Nigeria. The CGIAR's original 12 donor members had risen to 38 by 1988. The number of institutes it supports had risen from four to 13, and its funding had gone up to $250 million in current terms, with 40% being devoted to research on Africa. Four CGIAR centers (IITA, ILCA, ILRAD, and WARDA) are based entirely in Africa, ICRISAT has a very substantial investment there, and most of the remaining nine centers have staff outposted there. In addition there are two other internationally supported research institutions based in Africa (ICIPE and ICRAF), and the Fertilizer Center (IFDC) has a major program there.

Numerous collaborative research networks have been set up, often assisted by regional organizations, such as CILSS in the Sahel and SADCC in Southern Africa, or bilateral donors, such as France, the US, UK, Germany, Sweden, etc.).[1] The IARCs often act as lead agencies in these networks. International development-assistance agencies, including FAO and the World Bank, have expanded their support to research, both through institution building and research-oriented projects, while the World Bank has played a considerable role in mobilizing donors for the Special Program for African Agricultural Research (SPAAR).

The interaction of national and international activities aimed at strengthening agricultural research in Africa has been synergistic, not only in raising national capacity to do research and heightening international perceptions of Africa's problems and needs, but also in institution building and program planning. In this sense, the establishment of ISNAR in 1979 with the mandate to assist in the development of NARS has been of particular benefit.

1. The French donor institute (CIRAD), in particular, has maintained a long tradition of close scientific associations with African countries. It currently has about 550 researchers working in developing countries, in addition to a strong and sophisticated scientific base in France. Its 1989 research budget was equivalent to US$142 million.

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Table 15.
Scientific Manpower Resources for Agricultural Research in sub-Saharan Africa

Countries	National Agricultural Research Services research staff (BS and higher), 1980-86 (number and percentage/average)				Scientists with postgraduate MSc & PhD or equivalent degrees at institutes of higher agricultural education, 1980-86
	Total Researchers	% Expatriates	Postgraduates % of Total Researchers	Postgraduates % Nationals	
Western Africa					
Benin	45	7	73	71	26
Burkina Faso	114	48	—	—	42
Cameroon	187	33	—	—	—
Cape Verde	16	19	57	45	0
Chad	28	29	—	—	28
Gambia	62	27	—	—	0
Ghana	138	6	74	69	142
Guinea	177	—	—	—	—
Guinea-Bissau	8	13	75	71	0
Ivory Coast	201	73	—	—	59
Liberia	33	27	69	57	31
Mali	275	11	29	20	66
Mauritania	12	—	92	—	0
Niger	57	56	—	—	18
Nigeria	1,005	—	—	—	637
Senegal	174	29	—	—	56
Sierra Leone	46	—	—	—	65
Togo	49	24	—	—	21
Subtotal	*2,626*	*31*	*50*	*29*	*1,191*
Central Africa					
Burundi	53	43	85	73	17
Central African Republic	—	—	—	—	11
Congo	68	46	—	—	51
Gabon	24	58	71	30	10
Rwanda	34	28	—	—	8
Sao Tome & Principe	3	—	—	—	0
Zaire	43	—	23	—	124
Subtotal	*225*	*43*	*60*	*59*	*221*
Southern Africa					
Angola	28	46	46	0	—
Botswana	50	56	73	38	0
Lesotho	18	50	67	33	0
Madagascar	83	12	48	40	36
Malawi	80	6	30	26	41
Mauritius	99	—	36	—	17
Mozambique	77	83	83	0	33
Swaziland	11	36	44	17	27
Zambia	111	49	61	24	21
Zimbabwe	153	—	45	—	32
Subtotal	*710*	*41*	*52*	*24*	*207*
Eastern Africa					
Comoros	14	50	50	0	0
Ethiopia	142	6	43	40	68
Kenya	483	16	45	—	242
Seychelles	7	38	38	0	0
Somalia	31	13	9	—	57
Sudan	206	—	81	—	164
Tanzania	276	22	61	49	168
Uganda	168	—	—	—	56
Subtotal	*1,326*	*17*	*54*	*44*	*755*
Total	**4,888**	**29**	**53**	**38**	**2,374**

Source: Jain (1990).

Table 16.
Expenditure on Agricultural Research in sub-Saharan African Countries (Average, 1980–85)

Country	Expenditures (Millions of 1980 US Dollars)	Expenditures per Researcher	Expenditures (as % of AgGDP)
Western Africa			
Benin	2.383	113,634	0.32
Burkina Faso	15.568	134,029	1.74
Cameroon	15.069	92,163	0.74
Cape Verde	0.320	22,860	1.23
Chad	1.481		0.33
Gambia			
Ghana	3.344	25,821	0.11
Guinea	5.605	31,667	0.66
Guinea-Bissau	0.907	113,345	0.68
Ivory Coast	28.330	141,625	1.09
Liberia	5.247	166,672	2.81
Mali	12.552	45,645	1.18
Mauritania	0.501		0.18
Niger	1.994	33,771	0.19
Nigeria	92.393	91,958	0.59
Senegal	13.206	93,275	1.54
Sierra Leone	0.946	15,405	0.22
Togo	6.174	138,808	1.46
Subtotal	*206.020*	*84,045*	
Central Africa			
Burundi	4.381	74,251	0.52
Central African Republic			
Congo	2.494	33,703	1.34
Gabon	2.494	103,925	
Rwanda	2.004	65,668	0.23
Sao Tome & Principe	0.164	81,846	0.74
Zaire	3.820	93,259	0.19
Subtotal	*15.357*	*75,442*	
Southern Africa			
Angola	4.335	154,816	0.24
Botswana	5.849	113,634	4.24
Lesotho	6.043	335,726	3.38
Madagascar	7.318	107,016	0.38
Malawi	4.902	59,778	0.52
Mauritius	5.546	53,616	2.79
Mozambique			
Swaziland	2.472	348,740	1.87
Zambia	3.576	37,942	0.69
Zimbabwe	17.448	115,941	1.91
Subtotal	*57.489*	*147,468*	
Eastern Africa			
Comoros			
Ethiopia	11.323	94,053	0.21
Kenya	28.397	67,927	0.87
Seychelles			
Somalia	0.322	9,476	0.03
Sudan	13.683	74,863	0.31
Tanzania	20.417	54,138	0.64
Uganda			
Subtotal	*74.142*	*60,091*	
Total	**353.008**	**72,219**	**0.54**

Source: Jain (1990).

Nevertheless, much remains to be done to reinforce NARS and build on past growth. Many African NARS are still young and understaffed, and they lack experienced management to handle all the problems facing their countries. There is a higher proportion of expatriate researchers there than in any region, except possibly the South Pacific. Numbers of workers with advanced degrees should be increased, and some NARS appear seriously underfunded.

Strengthening Research Capability to Meet the Needs of the Future

Experience at ISNAR and elsewhere suggests that the following are of particular importance to the effectiveness of a NARS:[2]

1. strong and consistent government support;
2. good strategic planning and policy capability;
3. sound organizational structure for program development;
4. critical mass of well-trained, and well-managed staff;
5. in-country research and training linkages with universities and the private sector;
6. external linkages for research, training, and information;
7. excellent linkages to the technology-transfer system and the users;
8. effective monitoring and evaluation procedures.

Strong and Consistent Government Support

The most tangible evidence of government support to research is the financial backing it gives to the NARS. Moral support to research management is also very important, as is a dialogue between policymakers and research managers on the state of the agricultural sector, the impact of policy on farmers' behavior, and the formulation of a national research strategy.

Over the past 20 years, FAO, the World Bank, and others have suggested various normative targets as desirable goals for financial support to agricultural research. The most widely used indicator is the ratio of research expenditure to the value of AgGDP. A target of 0.5% of AgGDP by 1985 was suggested for developing countries by the 1974 UN World Food Conference. This was later increased by FAO to 1% for 1990 and to 2% by the World Bank. Developed countries spend between 1% and 2% of their AgGDP on public research. Additional amounts are also spent on agricultural research by the private sector.

Table 16 shows that the average for Africa for the period 1980–85 was 0.54% of AgGDP, with 12 countries (28%) spending less than 0.5%, another 10 countries (23%) spending 0.5 to 0.99%, nine countries (21%) spending between 1% and 2%, and four countries (9%) spending over 2%.

This, in fact, is quite a commendable performance. In most other developing regions, there are not as many countries spending 1% or more of their AgGDP on research. However, most of the countries spending over 1% in Africa had a high expatriate component, and their NARS were small, with only two out of 13 having more than 200 scientists. Comparisons with Asia, where a majority of NARS have over 1000 scientists but few expatriates, suggests that as systems increase substantially in numbers and no longer need to rely on expatriate staff, their costs per scientist and their expenditure-to-AgGDP ratios go down. Also, as the size of the agricultural sector increases, the ratio of research expenditure to AgGDP tends to decrease. There is, in fact, no empirical evidence concerning the optimum level of expenditure in relation to AgGDP for an effective research system, nor is it desirable to spend more money than necessary to achieve a 2% goal simply because a country has a large and productive agricultural sector. There is a limit to absorptive capacity for money. For purposes of planning and monitoring, it is useful to have normative guidelines, but these must be verifiable by broad experience and applied with discretion at the level of individual countries in the light of their goals and resources.

2. ISNAR identifies 12 critical factors essential for success under three headings of policy, structure and organization, and management. The eight items listed here subsume those 12 critical factors.

What is important is to ensure that a system is adequately funded to attract and retain good staff, that the funding does not fluctuate inordinately from year to year, that funds are not being wasted by bad planning and excessive dispersal of resources among too many research programs and inadequately equipped stations, that there remain sufficient operational funds in real terms (including hard currency) to enable effective laboratory and field work to be undertaken after staff are paid, and that there is a capital reserve to provide for major repairs, replacements, or additions to buildings and equipment without jeopardizing the normal operation of the system.

On a number of these points there is cause for concern in Africa:

1. Eleven countries are spending less than 0.35% of their AgGDP on research. Some of these have a considerable number of expatriates, and half are experiencing civil strife and unrest. It seems unlikely that their staff are able to do good research.

2. Between 1960–64 and 1980–85 the annual growth rate of scientific staff numbers has been around 4%, whereas that of research budgets has only been 3%. This suggests that manpower planning is out of line with financial planning. The usual result, now clearly visible in data from a number of African countries, is for operational funds to be cut so that salaries can be maintained. Larger staffs may add prestige to management, and a reluctance to reduce salaries or get rid of trained staff is understandable, but the result is self-defeating if the productivity of the system declines.

3. Several published studies show that there is a high degree of instability in the allocation of funds to research in real terms, both from year to year and within years, among the subsectors, institutes, or programs of a system. Sometimes this may be due to donor inconsistencies, but whatever the cause, instability is inimical to good research.

4. There has been a proliferation of nontechnical support staff beyond the apparent needs of efficient station management, and this has exacerbated salary crises.

Statistics may show that countries are spending 1% or more of their agricultural GDP on research, but if this is heavily dependent on donor money, as is commonly the case in Africa, the data may create a sense of false security. For a NARS to be truly sustainable requires a deep commitment from its own government, and in a number of African countries, that is not yet the case.

Effective Linkages between National Planners and Research Managers

Agricultural research in developing countries is often located in a directorate of the ministry of agriculture, or sometimes of science and technology. Its role in the development process is minimal, as are contacts between research managers and national planners. This leads to perceptions in government that research is out of touch with the real needs of the country. Among researchers, it leads to perceptions that they are being given inadequate resources to meet unrealistic planning goals which they have had no part in formulating.

This situation is gradually changing to one of closer partnership between policymakers and research managers as the key role of agriculture in economic and social development is being recognized. The research service is being called on more frequently to advise and consult with policymakers and to undertake specific tasks related to national problems on what is in effect a contractual basis. NARS can, and must, provide governments with information to help them with decision making, but in order to do so, their staff must have greater visibility and competence. In most countries of Africa, this process is still in an early stage, but Jain (1990) cites examples from several states where new mechanisms are being initiated to align agricultural research policy, programming, and priority setting more closely with national planning and policy formulation. For this to be effective may require the following actions:

- explicit recognition of the importance of agricultural research in the development process by the ministry or ministries responsible;

- granting of adequate status to the chief executive of the NARS;

- creation of a strong planning unit in the NARS, with capability in social sciences as well as technical competence;

- the formulation of a strategic plan for national agricultural research, with related financial and staff-development horizons;

- establishment of an appropriate mechanism to link research planners with the government departments responsible for national policy and resource allocation and to provide inputs from other services to agriculture (extension, etc.) and the private sector.

Determination of agricultural research policy is essentially an interministerial exercise, and one important issue is where such a mechanism is best located. In Africa, more commonly than in most other developing regions, agricultural research forms part of a ministry or council of science and technology (or the equivalent), rather than of the ministry of agriculture. The former usually offers a better base for managing resources (people, facilities, and funds), but if agricultural research is not to be based in the ministry of agriculture, there should be very strong representation from that ministry and from the farming community in determining the research program.

Conditions for a Well-Structured NARS

There should be a suitable structural and organizational arrangement for making sure that the research program is relevant to national objectives. One common arrangement to ensure that this type of interinstitutional interaction occurs is the establishment of an "apex body" with the authority to make decisions on agricultural research policy and endorse broad guidelines to the NARS. These decisions are based on information and analysis supplied by a technically competent secretariat. This is an especially valuable arrangement when a number of ministries, universities, and/or other agencies are involved in agricultural research for the country. Ideally, the apex body advises the government on the allocation of funds to the various research institutions that make up the NARS. It also endorses the composite national agricultural research program emerging from the research institutions and confirms that the balance among commodities and national objectives is in line with the original guidelines. The apex organization has an important role in deciding initial broad allocations among the main research institutions as a first step in determining the national research program. However, the internal structure of each institution is also critically important.

Appropriate authoritative bodies must make decisions about which main research thrusts are to be pursued within the mandate of the institute, as well as on their shares of resource allocation. Further decentralized groups are necessary to reach decisions at the third level of choice, where proposals for experiments and studies are most relevant, and to reduce major constraints to productivity with each research thrust. The eventual national agricultural research program is the aggregation of all approved experiments and studies. Structurally, this requires three levels of bodies to make decisions. Organizationally, the bodies should have appropriate membership, and operationally, each set of bodies should use some method of priority setting to assist their decision making. Ideally, the priority-setting method should be transparent, systematic, and appropriate to the level of decision.

In order to husband scarce resources, efforts must be consolidated and concentrated on achieving effective coverage of the main agroecological zones. High priority must be given to formulating the national agricultural plan. This may involve difficult decisions in terms of the commodities on which to focus and the priorities for regional coverage.

It is important that countries avoid the pitfall of fragmenting the planning and implementation of research among a plethora of ministries and departments. It is especially desirable to maintain close linkages among research units working on crop improvement, animal management, and forestry/agroforestry. In some countries, these are located not merely in different departments of a ministry, but in different ministries. As well as causing problems with planning and allocation of resources to research, this defeats the objective of developing more effective and sustainable land use. It also blocks the use of a systems approach, which would allow access to the complementary aspects of the sectors involved.

Making Effective Use of Limited Staff Resources

Among developing regions, Africa faces some of the most taxing problems of managing limited resources effectively. According to ISNAR data, over 60% of African countries had less than 100 scientists in their public-sector agricultural research institutions in 1980–86, and 42% had under 50 scientists (table 16). Conversely, only Nigeria had over 1000 scientists, and no other country exceeded 500. By comparison, 10 out of 14 Asian countries for which data are available had more than 1000 scientists; only three had fewer than 500.

While large size does not guarantee high quality, there are certain disadvantages associated with small research systems. Most notably, these include a lack of flexibility, an inability to devote a critical mass of interdisciplinary staff to priority problems, and difficulties in providing adequate coverage of agroecological and social diversity. Small systems generally have small budgets, and even when those budgets represent a satisfactory share of AgGDP, these systems cannot provide their scientists with highly sophisticated and expensive equipment. This limits their freedom of choice in the kind of research they can do, although the range of problems facing them may be as demanding as those confronting larger NARS. Therefore, small systems need high-quality staff to both plan and execute research.

A further constraint in Africa due to the smallness of many NARS is the relatively low number of national scientists with an advanced degree. Although the *proportion* of postgraduates is relatively high compared to NARS in other developing regions, the absolute numbers are larger in other regions because their average size is greater. There are a considerable number of national scientists with postgraduate degrees in university faculties, but in many cases their links with public-sector research institutions are not close, nor is university research well integrated with that of the NARS.

In order to strengthen the long-run capability of NARS in Africa to do quality research, as well to as to increase their near-term coverage of commodity, regional, and on-farm research, a number of measures are required:

- a long-term commitment to institution building by African governments and donors;
- concentration of effort on a smaller and less diverse range of priority goals;
- Greater use of devices that create a critical mass of scientific effort, such as national commodity programs in larger countries and participation in regional or other research networks with other countries;
- avoiding excessive dispersion of staff among a plethora of regional experiment stations and substations;
- developing national staff training plans to upgrade staff competence and to fill gaps in commodity and disciplinary coverage (such plans should involve both university training and shorter courses at home or overseas, including scientific, technical, and managerial training. Areas of weakness are business management, natural resource management, post-harvest technology and marketing, livestock management, forestry, economics, policy analysis, and most social sciences);
- strengthening national universities to undertake research of national importance, either on a collaborative or a contractual basis, with units of the NARS;
- establishing personnel policies that offer incentives to well-trained staff to join the national research services and remain with them (the reward system should not necessarily be based on numbers of publications, but it should be geared toward developing the kind of research output the country needs);
- expanding linkages with the private sector wherever it has an interest in research and the competence for it;
- developing close linkages with the IARCs in research, germplasm transfer, information, and training;
- improving information systems and developing appropriate national mechanisms for data collection, analysis, storage, and retrieval and for applying information to the programming and planning of research.

Good Linkages with Other National Bodies in Research and Training

The research capability of most developing countries would be enhanced if linkages between public-sector institutions, universities, and the private sector were better developed.

The role of the universities in training staff for research and technology-transfer services is crucial. They should also be taking a larger part in collaborative or contract research in partnership with the NARS. There are disciplinary strengths in university faculties which complement those in the NARS, particularly in the physical sciences (e.g., soil/plant/water relationships), molecular biology, and the social sciences. In some cases this complementarity has not been developed because neither the university faculty nor the NARS staff make a real effort. It may also be because the university has an inadequate budget for research or that it lacks the facilities or the practical experience in teaching and in supervising research — especially applied research with a practical orientation. This type of research is not always seen as a university responsibility by faculty members.

It is not easy to overcome an attitude of this sort, and it requires a genuine commitment by both ministries concerned, as well as by their scientific staff. This is where a national-level agricultural research planning and coordinating body can be very valuable. It can ensure that university participation is in line with national priorities and that it is complementary to the work of the NARS. This body can also provide additional funding as needed to upgrade university research and graduate-training capabilities.

Swanson and Reeves (1985) have suggested a relatively modest 10-year target of 5000 graduates for the West African countries alone, which should expand national research staffs over and above the current rather high wastage levels. This would triple the existing number of national scientists in the NARS there, but achieving it would put extremely heavy demands on the managerial and general absorptive capacity of the NARS, as well as on university teaching faculties.

A more realistic target would recognize that training and institution building is a long-term commitment and that simply providing more money and staff to NARS is likely to be counterproductive.

Thus, there is an important need for NARS to prepare comprehensive national staff development plans (including personnel policies) and related training programs in close cooperation with national planners and university authorities. Such plans would serve as a blueprint not only for in-country training by domestic institutions, but also for international and bilateral donors and the international and regional agricultural research institutions, who have an important part to play in assisting the development of NARS.

In most African countries, the private sector does not play a major role in research. Expectations that it would become more involved in other activities related to agricultural development (such as extension, input supply, agroindustries, and marketing) when parastatal control was relaxed have not always been realized, either (Lele 1989). Nevertheless, private industry is active in some fields, such as research on tobacco, sugarcane, horticulture, hybrid maize, as well as in seed production. Research contracts from NARS to private organizations for specific tasks or for collaborative research should not be dismissed. It is also in the interests of the NARS to encourage and assist private seed firms with advice wherever possible.

External Linkages and Their Role in Research and Institution Building

The massive expansion of external support to agricultural research in Africa since 1970 was noted earlier in this section. There are now about 15 international institutes either located in Africa or with active research staff outposted there. In addition, there are numerous international and bilateral research projects or projects with components of research, sometimes several in one country. There were over 50 agricultural research networks and subnetworks in Africa on a recent count (Plucknett, Smith, and Ozgediz 1990). These cover most major food crops and livestock species, as well as some aspects of research on natural resource management, ecology, and farming systems. Activities covered by IARCs, as well as international and bilateral projects and networks include not only research, but also training and information, so they have an important role in institution building.

Apart from their direct participation in research on African commodities and problems, a particularly valuable function of the IARCs and some bilateral

programs, is to provide NARS with access to facilities they could not otherwise afford, such as germplasm banks, sophisticated equipment, and worldwide sources of knowledge.

It is clearly vital for NARS to be able to take full advantage of those resources – to complement their own research rather than as a substitute for it. It is also important to recognize the fact that the IARCs do not work on export and nonfood commodities, and their research on natural resource management has been rather limited for the most part.[3] In these respects, and for adaptive research to capture spillovers and on-farm research at the grass-roots level, the NARS are largely on their own.

It must also be stressed that external resources are not an unmixed blessing. The NARS benefit from the IARCs, but the IARCs depend heavily on them for adaptation and verification of their research output. Networks are proliferating in their number and scope — their potential is considerable — but they are not all of equal value to the NARS. In addition to direct support to NARS and to networks, donors have literally hundreds of research-related projects or research components of projects in Africa. Not only do these make heavy demands on NARS, but they sometimes draw staff away from them.[4]

It is urgent to find ways to enable NARS to extract maximum benefits from external resources without overstretching their absorptive capacity to the point of counterproductivity. Three basic essentials are

1. A strong adaptive research capability must be developed. Screening and adaptation of imported technology requires efficient, well-trained staff at the national level. Capturing the flow of information coming in from spillovers may be less of a problem than knowing what to do with it. Donors and governments need to be aware of this need when allocating resources to NARS.

2. Well-defined national research plans should have related programs that integrate the NARS, the universities, donor support, IARC collaboration, and network participation into national research priorities, leading to the creation of greater institutional capability.

3. International and regional research activities in Africa should be rethought and reoriented to reduce overlapping, increase the efficiency of resource use, and ease the burden on NARS. This will be discussed further in the last section of this paper.

Research and Technology Transfer

Government Support to Extension in Africa

Research and extension services form part of a total system dedicated to providing farmers with the knowledge, advice, and materials required to increase their agricultural production and incomes. But experience in most developing regions has shown that relations between NARS and extension services or other organizations working on technology transfer are a weak point in the chain linking the generation of technology to its end users.

The reasons for this weakness lie partly in the fact that although their ultimate goals are (or ought to be) the same, the functions of the two services are very different. One develops new knowledge and materials; the other transfers that knowledge to end users. The products of the research system are not generated as a smooth flow of inputs to extension services but come at uncertain intervals and are of varying nature and importance. Research can function up to a point without extension, but extension loses its value to farmers if it gets no (or irrelevant) information from research. Ideally, perhaps, there should be only one unified system (as is the case with some individual, high-priced commodities). But the different functions, methods, and structures of research and extension probably preclude this on a national scale, where many different and complex problems have to be covered.

3. Lele (1989) states, "Despite the emphasis placed on export-led growth in policy reform programs in Africa, there has been little discussion of or support from the international community for export crop research, except through individual bilateral efforts—and even these are atrophying with the passage of time."
4. Oram (1987) observed that in the early 1980s there were about 650 such projects in 30 African countries. This review involved only 10 major donors, whereas Lele (1989) states that the number of donors involved in *each* of the six African countries covered by her study ranged from 25 to 32 between 1970 and 1984.

If this is not feasible, however, it seems desirable for governments to be evenhanded in supporting their separate research and extension organizations, so that neither is unduly impeded by the inadequacy of the other in fulfilling national goals for the agricultural sector.

Historically, this has not always been the case. Governments and donor agencies have tended to pursue the strategies that they felt would most expeditiously produce results, so support for research and extension has not risen in parallel.

The uneven pattern of past expenditures on extension in Africa compared to that on research is shown below (in millions of 1980 US dollars):

Table 17.
Expenditures on Extension in Africa

	1959	1970	1980
Research	119	252	425
Extension	238	481	515

Source: Judd, Boyce, and Evenson (1983).

These figures do not include international agricultural research expenditures in Africa, which would amount to another US$50 million in 1980. No international group finances agricultural extension.

Since 1980, expenditures on agricultural research have continued to rise fairly sharply in Africa, both nationally and internationally, as additional international programs have been opened up there.

Howell (1989) quotes figures on expenditure-to-AgGDP ratios for extension, which indicate that in 1980, the countries of West Africa were spending 1.28% of the value of their gross domestic product on technology transfer, and East African countries were spending 1.73%. Southern Africa was only spending 0.46% at that time, but the aggregate for Africa was greater than the expenditures on research.[5]

The report of a World Bank symposium (Roberts 1989) notes that financial support to extension is often precarious, and there are fears that the budgets of most public or parastatal extension services would be unsustainable if donor funding were to be withdrawn. *This puts a premium on developing inexpensive and cost-effective approaches to technology transfer.* Howell (1989) makes the following comment: "This decline in the importance of extension is only partly the result of new public expenditure priorities. More important, and contributing to resource allocation decisions, has been the declining effectiveness of the extension services."

This conclusion is somewhat surprising in view of the fact that by 1985 the World Bank was financing 51 projects with extension components in 26 countries of sub-Saharan Africa, often with cofinancing from other donors (Baxter 1989). Perhaps it is simply too early to expect a significant impact. A 1985 review of ongoing Bank investments in extension in 10 countries by the Bank's Operation Evaluation Department concluded that "experience with the T&V technique of extension suggests that *at least 10 to 15 years are needed to get the system firmly in place and develop a professional field-based system* [italics added]" (World Bank 1990).

Indeed a major complaint of extension staff is that donor support is often phased out before an extension organization is properly established and the system is sustainable.

What are the problems constraining the effectiveness of extension, and how can its impact be speeded up?

Characteristics and Constraints of Extension Work

Many of the problems affecting the efficiency of technology transfer as well as its costs arise from the nature of extension work:

1. Extension does not generate technology *de novo*. It is the main (although not the only) vector to the farmer of technology derived from the NARS. If the NARS is aloof, or not delivering technology appropriate to farmer needs, the extension staff is hamstrung.

2. Because its main role is knowledge and material transfer, extension is geographically dispersed, it works mainly downstream at the farm end.

5. IFAD has stated rather boldly that "a persuasive case can be made that substantial investment in extension (perhaps 3% of agricultural GDP) will be necessary to disseminate improved technology to the large numbers of low-resource farmers." However, the basis for this estimate is not specified, and there is no hard empirical evidence to indicate what an optimum level of expenditure should be.

Good logistical support, especially telephones, transportation, and audiovisual equipment, is critical to effective operations.

3. To facilitate close contacts with farmers, conventional extension systems substitute staff numbers for quality, with only a small graduate component.[6] Large staffs lead to high recurrent costs, difficult managerial problems, and a need for close monitoring of poorly trained field workers.

4. Extension organizations tend to be hierarchical and bureaucratic, with an inflexible chain of command from the center to the field. The top-down nature of extension messages is frequently criticized.

5. Technology-transfer arrangements are often fragmented. There is usually a conventional nationwide extension system covering food production plus specialist services for certain high-value commodities, irrigation, and animal health. Those services are often quite effective.[7] Overall efficiency is not necessarily served by absorbing them into one national service, even when this might theoretically lead to better-integrated farming systems.

6. Good linkages between research, extension, and farmers, as well as good feedback linkages to policymakers, are essential to effective technology transfer. Even where research-extension linkages are good, the absence of suitable arrangements for producer participation and the inaccessibility of national policymakers to research and extension staff may defeat the objectives.

7. Regulatory tasks of one kind or another absorb resources and staff time and may generate producer resistance.

8. In a majority of countries, the universities do not participate in extension, and since faculty members have little contact with farmers, the courses are largely theoretical.

9. The adoption of new technology is often constrained by government policies and other externalities, especially limitations on the access of farmers to inputs and credit, and extension personnel are unable to overcome these problems.

Improving the Effectiveness of Technology Transfer

There is a growing sense of the need to link research and extension more closely with each other and with farmers. Collinson (1987) has suggested that the critical break in the research-extension-farmer chain occurs not between research and extension but rather between the research and extension establishments on the one hand and the farmer on the other. While this is often the case, there is abundant evidence of a serious gap at the institutional level. Research and extension staffs have therefore been experimenting with ways to strengthen this bond.

These include variants of the training and visit (T&V) system — actively being propagated in 20 African countries by the World Bank; the establishment of extension-liaison units with specialist extension staff located in the NARS — Zambia; and the development of research stations in agroecological zones which function as (a) the main foci of multidisciplinary applied research, (b) the coordinating centers for farming systems and on-farm research in the zone, (c) the regional headquarters of the extension service, and (d) the base for its subject-matter specialists.

It is important in designing new technology to note that the educational level and technical competence of the average field-level extension worker is not high. The T&V system aims to offset this by providing simple programmed messages to field workers at regular intervals. It is questionable whether this approach is adequate for training farmers in the adoption of more complex techniques such as integrated pest management, organic farming, or alley cropping.

In order to overcome this problem, some countries have raised the proportion of graduates in their extension services, both by strengthening the subject-matter–specialist component and by replacing a proportion of the low-level field staff with graduates. It may be feasible to do this without affecting the frequency of contacts with farmers if the exten-

6. One extension worker to 1000 farmers in rain-fed areas or to 500 farmers in irrigated land is a commonly cited normative goal.
7. The CFDT cotton operations in 24 African countries, the BAT tobacco project in Kenya, and the Ghana Grains Development Project are successful examples.

sion staff are mobile, well-equipped with modern communications equipment, and well-trained in techniques of communication. Unfortunately, this is often not the case.

It is evident from recent conferences on agricultural extension in Africa that there is considerable disagreement about the most effective approach to technology transfer there (Belloncle 1989). There are both strong advocates and strong critics of the T&V philosophy. Some African specialists feel that African farmers resent the paternalism of the T&V system and would respond better to initiatives that would help them develop their own advisory services through group action (Howell 1988). It is claimed that this is more in keeping with the social structure in much of Africa, and among other things would provide better opportunities for the participation of women farmers. While this is an attractive argument, it leaves open the issue of who pays for the system, how the group participants obtain their advice and the inputs to put it into practice, and how the research system interacts with the groups for testing new technology, diagnosing problems, and obtaining feedback. Experience with group approaches suggests that official research and extension participation is desirable on a partnership basis. Zimbabwe, Kenya, Mali, and Niger are examples of African countries with evolving group-action programs.

ISNAR has conducted two research projects designed to provide practical guidelines on ways to strengthen links between research institutes, farmers, and technology-transfer agencies. The first study focused on the organization and management of on-farm, client-oriented research. The second focused on the role of research–technology-transfer links in ensuring that relevant technologies are transferred to farmers effectively and efficiently. The studies were conducted with a wide range of national research systems, including five in Africa (Nigeria, Senegal, Tanzania, Zambia, and Zimbabwe). They focused on five key areas:

- the policy and institutional context of linkages;
- organizational factors affecting linkages;
- types of linkage mechanisms;
- staff management issues;
- the need for active management of linkages.

A review of the findings of these two studies (Merrill-Sands and Kaimowitz 1990) illustrates the need to avoid facile and dogmatic generalizations concerning the appropriateness of technology-transfer systems. There is no single recipe for strengthening linkages, and the policy and institutional context largely determines the strategies and mechanisms that can be used. Appropriate structural mechanisms vary with the size, resources, and complexity of the institutions involved. In addition to structural interventions, there are also other types of mechanisms that can be used, either alone or in combination, to strengthen linkages and build effective contacts with technology users. Dynamic and flexible leadership and management skills are essential to create the conditions necessary for productive collaboration and to motivate staff while overcoming status problems.

Clearly, much needs to be learned about the circumstances under which various technology transfer mechanisms function most effectively (policy and institutional context, environment, demographic situation, type and system of farming, farmer education, etc.), as well as their comparative costs. This suggests that continuing research, supported by case studies, is desirable, probably under the aegis of the impact-evaluation mechanisms discussed in the section covering research on technology transfer, below.

3

Strategies for Agricultural Research and Technology Transfer Related to Food Security

Achieving food security will require a carefully planned strategy involving a combination of measures to promote economic growth, agricultural development, and family incomes, as well as welfare measures to protect socially disadvantaged people. It will involve a large number of scientist-years, with research on macroeconomic and trade policy; on microeconomic policy at the local, farm, and household levels; on production and natural resource management; and on food consumption, income, employment, and welfare. Some of the issues involved are discussed here, focusing mainly on food-security policy, sustainable natural-resource management, and technological change.

Africa today faces tremendous problems created by climatic instability, food deficits, lack of foreign exchange, rapid population growth and other sources of environmental pressure, and limited progress in increasing food production. Given this state of affairs, it is clearly necessary to combine short-term pressures to push growth as fast as possible (consonant with sustainability, building on existing knowledge) with a longer-term approach aimed at developing new techniques and technological innovations. The longer-term plan would also cover problems that cannot be ameliorated significantly by short-term measures. Innovations must be based both on the application of state-of-the-art scientific knowledge and on a deeper understanding of the ecological and social diversity of Africa and its traditional farming practices.

The limitations of human resources and institutions discussed in chapter 2 are likely to have a negative effect on the capability for research and technology transfer through the 1990s and probably into the 21st century. Because of this, any strategy for the use of scarce resources will have to be highly efficient, with selective concentration of effort on ecological regions, commodities, areas of demographic pressure, and opportunities for progress through amelioration of identified constraints. One key element in developing such a program is to identify the main components of demand for research in broad terms and then to disaggregate demand by agroecological zone and target group. This will help sort out immediate opportunities from those goals that, although of high priority, have to be regarded as longer-term or more speculative for technical, institutional, or other reasons.

The constraints under which NARS currently operate in most African countries imply that many desirable research tasks will have to be deferred until late in the decade while a major institution-building effort is pursued, and only essential research priorities will be able to be undertaken in the short term. The screening process will be painful; thus, it is important to involve policymakers *and* users of research in planning and decision making.

The following high-priority areas of research are identified with respect to sub-Saharan Africa as a whole, although their importance varies within the region and at the national level. Discussion of national priorities is beyond the scope of this paper.

Developing a Strong Research Capacity for Policies on Food Security

In a region as large as Africa, with so many countries and with poor lateral communications, ensuring food security for everyone is a difficult task. Because of climatic conditions over much of the region, food security is not a goal that can be achieved by many countries solely through increasing domestic food production, although that is an indispensable step if economic chaos is to be avoided. A complex set of policies is necessary — policies that include investments to accelerate general economic growth, increasing the supply of food, raising the incomes of the poor (if possible through measures that also stimulate economic growth), promoting exports to finance food imports or production inputs, targeting programs that provide food (or the means to buy it) toward chronically food-deficient segments of the population, and judicious investment in stock-holding and infrastructural development to provide stability and a safety net in emergencies.

A successful food-security program requires a sound policy framework, which is an area where many African countries still lack a strong analytical capability. Experience at IFPRI shows that research at both the macro- and micro-levels is needed to assist policymakers in developing food-security strategies that are both cost-effective and efficient in balancing urban and rural needs as well as those of producers and consumers. Since 77% of the African population is rural and the bulk of the poor live in rural areas, the policies that are crucial to food security are those that will stimulate agricultural production, increase farm incomes, provide additional off-farm employment and cash to buy available food when needed, and maintain a healthy rural population.

Effective research on food-security issues in Africa is hampered by several constraints:

1. NARS are generally weak in economics and social sciences, which make up only about 5% of their staff (compared to 44% in plant sciences, for example). This hampers their ability to understand farmers' problems and motivations, to deal with labor constraints, identify marketing needs, and improve the design of production and post-harvest technology. This weakness is an important factor in poor programming of research at the national level.

2. University social science programs are not well linked to those of public-sector institutions, and they tend to be theoretical in content.

3. Much of the policy research that is conducted is country-specific, ephemeral, and does not have wide relevance for Africa.

4. Although several IARCs, the World Bank, FAO, and others are working on policy issues related to food security in Africa, there is no coordinated network for policy research.

While continuing research at the national level is needed (especially on the impact of policies on farm and household decisions), it would be valuable to try to focus international efforts or regional policy networks on key issues with broad relevance across countries within major agroecological zones, across regional political organizations (SADCC, CILSS, etc.), export commodity producers, or other appropriate groups. One such example is the network between the University of Zimbabwe and Michigan State University, based at the University of Zimbabwe, that collaborates with the universities of Dar es Salaam, Malawi, Swaziland, and Zambia.

Issues of wide importance include the effects of exchange-rate reform, the potential for intraregional cooperation (e.g., in research, food trade, and food security), the impact of developed-country trade and aid policies on African agriculture, the economic and social costs of input subsidies and price-support policies, the effects of food aid on producers and consumers, the incentive role of infrastructural investment on food production, opportunities and requirements for labor migration between land-scarce and land-abundant regions (which, contrary to conventional wisdom, is now seen as having a positive long-term impact on farm productivity by channeling remittances to investment), the effects of security of land tenure on productivity and sustainability, etc.

Some issues are more controversial than others, and it may be useful for researchers to give priority to clarifying those. One example is the question of food versus cash crops. Research by IFPRI has shown this to be largely irrelevant in terms of any

adverse impact on household nutrition when cash crops are a main source of family income.

Improving Natural Resource Management

Characterization of Agroecological Potential

Africa has a wide range of agricultural environments, and an understanding of their nature and complexity is essential to the development of a sound strategy for food security and related research priorities based on sustainable natural-resource management. Research must be much more sensitive to physical, social, and economic variations in the environment. Particularly important in the rain-fed agricultural systems that predominate in Africa is the variation in the water balance.

Studies by FAO (1978) and others, as well as the work of the IARCs in Africa, show that the gross areas of the main agroecological zones are not greatly different, but both their short-run potential for accepting new technology and the type of technology appropriate to their resource endowments, especially land and labor, vary considerably (table 18). Their ability to provide food to support current and future populations also varies considerably. Thus, careful characterization of agroecological potential should be given high priority.

Agroecological data can be linked to socioeconomic characterizations through identification of "recommendation domains" or rapid rural appraisal techniques. This is one way for researchers to obtain a more precise understanding of why farmers do not always grow the "optimum" crop or adopt recommended packages of technology, and why they sometimes pursue apparently counterproductive courses of action. It can also contribute to the development of acceptable technological and land-use objectives as a basis for research programs, as well as social or other policies designed to combat environmental degradation.

The knowledge of the range of ecological and social situations in Africa must be progressively refined, and specific data bases on climate, soil, and vegetation will have to be established. The short-term benefits of this work are obvious: identification of representative experimental sites or of analogous ecozones for selective distribution of genetic material. However, there will also be major long-term effects: on developing more relevant research objectives as well as more precise targeting of technology, evaluation of its acceptance by farmers, and monitoring of its impact on the natural environment and productivity.

This linking of agroecological and socioeconomic information is regarded as a long-term priority because its benefits will be progressive and cumulative, and will greatly assist prospective planning. It should also be given priority because recognition of its potential is relatively recent and the methodology is still evolving, both in terms of the techniques of agroecological characterization and classification, and in linking this to spatial socioeconomic analysis.

Developing a Selective Strategy for Allocating Scarce Resources to Production

We have shown that because of population pressures, land is becoming scarce in some agroecological zones, although not universally, in Africa. We have also shown that the quality of the natural resource base for agriculture varies widely, as does the related agricultural potential, and for a number of reasons, that potential is not being realized, even where it is apparently high. This could be due to a number of things:

1. Farmers are still operating on a land-extensive strategy and are not very interested in using scarce resources to intensify production through technological change.

2. Improved technology is unavailable or inappropriate to farmers' needs.

3. There are binding constraints on the application of improved technology, even where it seems appropriate. The most important of these constraints are lack of access to yield-increasing inputs and labor shortages, especially at peak periods. Market factors may also limit the willingness of farmers to accept new technology.

Given the grave outlook for food security by the year 2000 and beyond (discussed earlier in this paper), it seems imperative to design a strategy for production that allocates scarce resources where they are likely to yield the highest returns to their use, without damaging the sustainability of the

Table 18.
Climatic Characteristics of the Growing Season of Four Locations in Nigeria and for Each Location, the Computed Net Biomass Production per Day and Yield for Phaseolus Beans, Maize, and Cassava

Location	Latitude	Ecological Zone	Growing Season (Days)	Radiation (Cal per cm^2/day)	Rain-fall mm/yr	Biomass Production (kg/ha per day)			Yield (ton/ha)		
						P[a]	M[b]	C[c]	P[a]	M[b]	C[c]
Kano	12°03'	Sudan savanna	138	471	869	93.5	129.0	182.0	4.3	10.1	—
Samaru	11°11'	Guinea savanna	187	452	1,095	84.0	120.3	169.0	4.4	11.2	12.4
Ibadan	7°29'	Savanna forest transition	276	400	1,227	59.4	99.6	133.0	6.9	8.6	15.1
Port Harcourt	4°5'	Forest	331	369	2,334	47.4	78.9	108.0	3.4	7.1	14.4

Source: Kassam (1977).

a. *P* = 100-day phaseolus beans.

b. *M* = 120-day maize. For maize the harvest indexes used were Kano = 0.45, Samaru = 0.5, Ibadan and Port Harcourt = 0.4.

c. *C* = cassava over full growing season.

resource base. This implies selectivity in terms of the potential productivity of the different agroecological zones, the crops and livestock produced in those zones, the inputs required to increase productivity, and the human resources. It means that research priorities will also have to be selective.

This targeted approach to research on agroecological zones will probably give priority at first to those that have reliable rainfall but are not excessively humid and to soils that do not present major problems (for example, the Guinean and Sudanian savanna zones of West Africa, the mid-altitude plateau zone of Southern Africa, and some high-altitude areas of Eastern Africa). In addition, it will be necessary to be selective in terms of demographic pressures on resources *within* specific agroecological zones.

In table 19, the countries of Africa are grouped in the main ecological zones according to low, medium, and high agroclimatic population density and the transitional zones between those densities. This is based on work by Binswanger and Pingali (1988), who postulate that at low-population densities, techniques that involve yield-increasing purchased inputs or that raise labor costs or labor requirements at peak periods are unlikely to be adopted on a significant scale. Tshibaka's (1990) analysis points to the same conclusions. This may help account for the paradox that most of the countries indicated by FAO as able to generate food surpluses are relatively land abundant, but they have a rather poor record of yield growth and are often food importers.

From this analysis, it is concluded that under land-abundant situations, researchers have less opportunity to achieve breakthroughs with fertilizers,

Table 19.
Sub-Saharan African Countries with Low, Medium, and High Agroclimatic Population Densities, by Ecological Zone for the Year 2000

Agroecological zone	Low population density	Transition to medium density	Medium population density	Transition to high density	High population density
Equatorial wet tropics	Congo Central African Rep. Equatorial Guinea Gabon Sao Tome Zaire				Mauritius
Coastal wet tropics	Ivory Coast Liberia Madagascar Guinea-Bissau	Sierra Leone Guinea	Ghana Togo		Comoros Is.
Humid savanna (Guinean)	Angola Cameroon	Benin Mozambique			Nigeria
Subhumid savanna (Sudanian)	Zambia		Gambia Zimbabwe	Lesotho Malawi	Swaziland Reunion
Semi-arid savanna (Sahelian)	Chad	Sudan	Mali	Botswana Burkina Faso Senegal	Cape Verde Mauritania Namibia
Tropics modified by altitude			Tanzania	Uganda	Burundi Ethiopia Kenya Rwanda

Source: Adapted from Binswanger and Pingali (1988), and FAO, UNFPA, IIASA (1982)
Note: Agroclimatic population density is defined as the total population divided by FAO's estimates of potential calorie production at the intermediate input level.
Low density = less than 100 persons per million calories of potential production throughout 2000-2025.
Transition to medium = will reach 100 persons per million calories of potential production throughout 2000-2025.
Medium density = between 100 and 250 persons per million calories of potential production throughout 2000-2025.
Transition to high = will reach 250 persons per million calories of potential production throughout 2000-2025.
High density = above 250 persons per million calories of potential production throughout 2000-2025.

herbicides, fertilizer-responsive varieties, or irrigation than where land is limited. In land-abundant areas, fertility may be maintained by fallowing, and additional output can be generated more easily and cheaply by expanding the area under crop, although labor may be a constraint, especially where trypanosomiasis limits the use of draft animals.

Thus, research that aims to raise yields through more conventional measures, especially fertilizer use, should be focused on higher-quality land in areas of more reliable rainfall with lower risks of crop failure, or with irrigation. Often, though not always, these areas are in regions of higher demographic pressure on land and better communications to markets, thus providing incentives to more intensive agriculture on a sustainable basis. Input supply and credit should also be given first priority in these areas. This approach could help conserve and concentrate scarce research resources and extension staff while national capabilities are being built up to tackle the long-term problems of more difficult environments.

Of course, such an approach raises issues of growth versus equity. However, the result of dispersing scarce resources across low- as well as high-potential areas, or on crops that are mainly of benefit to more affluent segments of the population, may be that neither growth nor equity is achieved. In some resource-poor areas, agricultural science may be unable to provide solutions, and the answers may have to be sought through social or other measures.

Expanding Research on the Role of Trees in Land Use

According to FAO data, trees still unaffected by agriculture cover about a third of the land surface of sub-Saharan Africa. Arable land represents only about 7%, and perennial tree crops represent less than 2%.

Trees are underestimated as an important factor in the food supply. If anything, there is hostility between foresters, farmers, and pastoralists because of competition for land — especially at the wet and dry margins of agriculture. Consequently, there is little interaction between agricultural and forestry research, and the potential contribution of trees to farming systems has been neglected. Reports from the World Bank and USAID concerning tree-based projects designed to halt environmental deterioration do not indicate a high rate of success in achieving sustainability goals.

The FAO Committee on World Food Security has pointed out that trees play a crucial role in sustaining food security in the following ways: contributing to *stability* by maintaining soil fertility and the hydrological balance, contributing to the *adequacy* of the food supply through direct and indirect contributions of tree and forest products to food and to fuel for cooking, and contributing to *access* to food by providing employment, income, and foreign exchange. Both forestry, and trees associated with agricultural systems, contribute to the well-being of rural households in Africa and provide sources of income. The committee states that multidisciplinary cooperation involving forestry, agriculture, and animal husbandry is the only way of controlling the progressive destruction of the forests, with the subsequent backlash on agriculture through erosion, desertification, and adverse impacts on climate.

Research is essential in order to change this situation and develop the latent potential of trees in land-use systems, and it must involve a range of disciplines. Yet research on forestry and, even more, on agro-silvi-pastoral systems in Africa is extremely weak; there are about nine times as many agricultural scientists as foresters in Africa. Forestry scientists and technicians are seven times more numerous in Latin America than in Africa and 20 times more numerous in Asia. Until recently, only two IARCs in Africa had tree-related programs, IITA and ICRAF.

Internationally, this situation has begun to change. Donor interest in halting forest destruction is strong, and the interlinkages in land use between trees and annual crops are likely to become a research area of increasing long-term importance. The CGIAR has formally agreed to support forestry and agroforestry research, with a major new forestry-research initiative being proposed and a program for conservation of forestry genetic resources planned. ILCA and ICRISAT have commenced work on agro-silvi-pastoral culture and trees in farming systems, and IFPRI is developing a research program on forestry policy. CIRAD and the Club du Sahel have commenced forestry and agroforestry studies in several West African countries, and ICRAF has launched a major network program, with activities in 16 African countries, often involv-

ing collaboration with other international organizations. There is a strong emphasis on the role of multipurpose trees in farming systems as a means of increasing productivity and sustainability in many of these programs.

While the outlook is encouraging, there are important hurdles to be overcome. The technology is new to some researchers and most farmers, and there are methodological problems in assessing the benefits. Fifteen African countries had fewer than 10 forestry researchers in 1986, and links between agricultural and forestry scientists are often weak — the two areas are sometimes even located in different ministries or government departments. Thus, a major effort will be needed to develop a critical interdisciplinary research effort on the role of trees in food security. This must be accomplished before the results obtained so far can be analyzed and widely applied and the scope of research extended.

Raising the Productivity of Farming Systems

Concentration of Research Efforts

In establishing research priorities, it is essential to identify the extent that the various commodities occur in various countries and regions and their contribution to those areas, so as to avoid the error of trying to cover too much with inadequate resources. While this is a criticism often levelled at the NARS in Africa, the IARCs are not immune to it either, as the history of IITA shows.

The principal food and nonfood crops produced in each major agroecological zone are shown in table 20 in volume terms, and the importance of the food crops in terms of cereal equivalent is illustrated in table 21. These tables show the following:

1. Cereals contribute 58% of the energy component of domestic food production, with maize, sorghum, and millet being the key crops. The importance of cereals is greater when imports are taken into account, since imports were equal to 23% of the total domestic food supply in 1987–88, and they consisted very largely of cereals.

2. Rootcrops contribute 30% of the dietary energy, with cassava, yams, and bananas/plantains being the key crops. However, the production of yams is narrowly distributed, with 95% of the entire world production originating in the coastal wet tropics of West Africa. Cassava and banana species are much more widely grown.

3. Food legumes, including groundnuts, contribute 12% of the recorded food supply. Cowpeas, groundnuts, and beans (mainly in higher elevations) are the principal crops, with groundnuts being grown both for direct consumption and for processing into edible oils.

4. The contribution of vegetables and fruits is often underestimated because there are inadequate data on production for home consumption. They contribute only about 9% to caloric intake, but their role in supplying vitamins and minerals to the diet is extremely important.

5. The most important crops not grown for direct food use are sugar cane (mainly irrigated), oil palm, rubber, cocoa, coffee, tea, tobacco, and cotton.[8] Oil palm, coconut, rubber, cocoa and robusta coffee are grown mainly in the wet, humid lowland tropics. Arabica coffee and tea are grown at higher elevations in the cool tropics, and tobacco and cotton are grown in the subhumid, seasonally dry tropics. The significance of many of these crops to food security lies not only in their export earnings, but in their high employment and value-added components. Coconut has a limited international research program, but none of the other crops does, and only cotton and tobacco are of significance to developed countries. How research and technology for their production and processing can be strengthened raises difficult issues of national and international priorities.

6. Ruminant livestock are concentrated principally in the East African highlands (especially Ethiopia), the subhumid zone of West Africa, and the semi-arid zones, where seasonal pasturage is a main form of land use. Cattle are the most important animals — for milk, meat, and work — although sheep, goats, and poultry are important in the tsetse infested humid zones and in the arid zone (ILCA 1988).

8. In terms of total area cultivated, cotton ranks seventh after maize, cassava, sorghum, millet, groundnuts, and rice.

Table 20.
Total Production in Cereal Equivalents of Selected Commodities in a Sample of sub-Saharan African Countries by Agroecological Zone, Average 1979–81

			Warm Tropics							Tropics Modified by Altitude					
Growing Season (Days/Year):			(365)	(364-330)	(329-270)	(269-210)	(209-150)	(149-90)	(89-0)	(364-330)	(329-270)	(269-210)	(209-150)	(149-90)	(89-0)
Commodity	Total (000 tons)		Peren.Wet	Wet	Humid	Seas.Dry	Semi-Arid1	Semi-Arid2	Arid	Wet	Humid	Seas.Dry	Semi-Arid1	Semi-Arid2	Arid
1. Wheat	1,333	1.93%			22		339	346			302		261	63	
2. Rice	3,588	5.20%	57	833	936	662	8600	122	99	2	7	3	4	3	1
3. Maize	14,816	21.47%	61	872	1,961	2,645	4,415	1,324	1,536	38	252	711	540	342	118
4. Millet	8,350	12.18%		20	135	591	2,680	2,844	1,867	1	12	113	50	23	14
5. Sorghum	9,621	13.94%	13	28	584	1,531	2,395	1,961	2,282	7	103	449	177	59	32
6. Potatoes	396	0.57%			9	75	68	45	54		21	51	45	26	2
7. Cassava	10,748	15.58%	176	2,459	3,409	2,078	2,004	379	44	81	18	44	46	9	2
8. Sweet Potatoes	792	1.15%	6	58	62	249	108	63	8		70	86	66	14	1
9. Yams	5,454	7.91%		780	2,601	1,942	130				3				
10. Bananas & Plantains	2,371	3.44%	96	584	603	244	86	46	29	12	44	405	192	27	3
11. Pulses	4,095	5.94%		137	224	544	753	827	358	20	146	765	180	91	51
12. Groundnuts	3,538	5.13%	31	253	327	479	1,221	774	334	8	7	70	27	7	1
13. Soybeans	180	0.26%			2	15	46	12	3		5	18	66	13	
14. Sugar	3,716	5.39%		563	664	536	861	167	248	1	97	137	341	101	
Totals	68,998	100.00%	439	6,588	11,515	11,614	15,626	8,903	7,209	169	784	3,153	1,732	977	289
Share of agroecological zone in total output			0.64%	9.55%	16.69%	16.83%	22.65%	12.90%	10.45%	0.25%	1.14%	4.57%	2.51%	1.42%	0.42%

Source: Broca and Oram (1991).

Table 21.
Percentage of Total Production of Selected Commodities in sub-Saharan African Countries, by Agroecological Zone, Average 1979-81

Growing Season (days/year): Commodity	Warm Tropics							Tropics Modified by Altitude						Cool Subtropics*		
	(365) Peren.Wet	(364-330) Wet	(329-270) Humid	(269-210) Seas.Dry	(209-150) S-Arid1	(149-90) S-Arid2	(89-0) Arid	(364-330) Wet	(329-270) Humid	(269-210) Seas.Dry	(209-150) S-Arid1	(149-90) S-Arid2	(89-0) Arid	(329-210) Hum–S.Dry	(209-90) S-Arid	(89-0) Arid
1. Bananas/Plantains	3.4	16.1	18.8	20..7	8.2	4.1	1.6	0.3	1.0	11.8	6.3	0.9	0.1			
2. Cassava	1.4	18.4	28.5	21.5	16.0	3.0	0.6	0.5	0.3	0.6	0.6	0.1				
3. Coconuts/Copra	17.6	17.1	42.1	23.2												
4. Groundnuts	0.8	6.8	9.5	15.2	33.2	22.0	9.1	0.2	0.2	1.9	0.7	0.2				
5. Maize	0.4	5.5	12.8	18.8	28.8	9.0	10.6	0.2	1.7	5.1	3.4	2.1	1.2			
6. Millet		0.2	2.4	10.6	30.6	32.2	21.2	0.1	1.5	0.7	0.3	0.2				
7. Palm Kernels	4.0	16.4	12.5	8.4	4.8	0.1	0.1	0.1	0.1	0.1						
8. Palm Oil	5.1	19.5	11.0	7.6	2.6	0.2	0.2	0.1	0.1	0.1						
9. Citrus Fruit		4.6	34.7	22.8	26.5	9.7	1.7									
10. Potatoes			3.4	18.2	18.3	9.2	10.8		4.2	16.4	12.9	6.1	0.4			
11. Pulses (cool)																
12. Pulses (warm)																
13. Rice	1.0	24.3	25.3	20.3	21.4	3.3	2.3	0.1	0.4	1.2	0.2	0.1	0.1			
14. Rubber		73.9	26.1													
15. Sorghum	0.2	0.3	1.0	7.7	14.6	11.3	23.1	0.1	1.0	4.9	1.8	0.9	0.3			
16. Soybeans			2.6	12.8	21.6	6.4	1.6		2.6	6.9	38.5	6.6				
17. Sugarcane																
18. Sweet Potatoes	0.5	5.2	8.8	27.6	12.9	5.8	1.1		4.8	7.4						
19. Wheat				0.7		14.3	22.7			21.8	18.6	4.5			0.3	1.4

Growing Season (days/year): Commodity	Warm Tropics				Tropics Modified by Altitude					Cool Subtropics*		
	(365-270) Humid	(269-180) Seas.Dry–S-Arid	(179-75) S-Arid–Arid	(74-0) Arid	(365-270) Humid	(269-180) Seas.Dry–S-Arid	(179-75) S-Arid–Arid	(74-0) Arid	Total	(269-180) S.Dry–S-Arid	(179-75) S-Arid–Arid	(74-0) Arid
20. Milk	2.2	14.9	24.1	21.5	1.5	8.7	3.5				0.5	
21. Sheep/Goat Meat	8.8	15.6	25.6	34.2					13.1	0.2	1.9	
22. Wool		14.7	22.2	29.9		11.7	3.9			3.3	5.0	3.6
23. Beef	4.8	19.7	62.0						12.8			

Source: FAO *Production Yearbooks* (various years).

Note: Percentages for specific commodities may not add to 100.

These percentages were found as follows:

1. The figures for the production of a commodity in each agroecological zone of each sub-Saharan African country were added across countries to obtain the commodity's Africa-wide output for each agroecological zone.
2. These totals were then divided by the total output of that commodity in sub-Saharan Africa.
3. It should be noted that, although FAO reports total outputs, the breakdown by agroecological zone is not known for some commodities in some countries.

*Climates where there is summer rainfall.

In terms of the aggregate size of the arable area devoted to their production and the number of countries where they occupy a significant share of total annual cropped area, there are only about six food crops that are so widely grown as to be termed "pan-African." In order of importance these are maize, cassava, sorghum, millet, groundnuts, and rice.

These six crops clearly merit high priority for research and technology transfer. However, analysis of land use by agroecological zone shows that there are nine other crops of subregional importance to the food supply. They include wheat, potatoes, and phaseolus beans in the East and Central African highlands and the Southern African subtropics; sweet potatoes, soybeans, and cowpeas in the subhumid and humid savanna zones; and bananas/plantains, oil palms, and yams in the wet tropics.

Poor and seasonally variable nutrition from natural grazing limits the potential of cattle for work and the production of meat, milk, and hides, and competition for land between humans and animals is reducing the availability of grazing land and annual forage crops. For these reasons, forage trees are becoming more important, and if they are leguminous, they have the added advantage of improving soil fertility. Wherever ruminant animals are not limited by the existence of tsetse flies, forage trees should also be given a high priority for research.

A number of other commodities are of local significance (for example, barley and teff in the highlands of Ethiopia, which has been suggested to constitute a special agroecological zone distinct from the rest of East Africa). The Technical Advisory Committee (TAC) to the CGIAR has identified nine such relatively minor crops. A case might be made that it is not equitable to ignore them.

These key commodities are relatively limited in number, but they are well suited to the agroecological zones in which they are cultivated. They also provide such a high proportion of nutritional needs, income, and employment to a majority of the population that research targeted toward them and the farming systems in which they predominate would seem to serve the interests of equity as well as of growth.

Therefore, it is suggested that the number of priority food commodities for research might be limited to about six in *each* major agroecological zone, giving priority to those that represent at least 5% percent of the total calorie production of the region, that generate high income both on and off the farm, and that are most important to the diets of the rural poor. IFPRI studies show the latter to be maize, sorghum, millet, rice, cassava, bananas and plantains, vegetables, and vegetable oils.

Escalating cereal imports, of which wheat constitutes 52% (table 22), provide a further argument for giving high priority to research on increasing domestic cereal production. The potential for wheat production in Africa is limited under current technology, so maize, sorghum, and millet (in the drier areas) should be given primacy. Technological research to make those cereals more acceptable as foods of convenience would also be beneficial.

Improving the Efficiency of Input Use

The question of how much effort should be concentrated in areas of high potential compared to areas of low potential is not alone in arousing controversy. The issue of the importance that should be given to low-input technology versus technology dependent mainly on chemical inputs is also a controversial one. Rather than being argued emotionally, such issues should be examined objectively in terms of their technical and economic potential for raising production efficiently without damaging the environment. As far as Africa is concerned, the following must be considered:

1. In almost every country, agriculture is not merely low-input, but almost "no-input" from the point of view of fertilizer, pesticides, or mechanization. Nowhere in the world is input so low over such a large area. There are a few places where fertilizer or pesticide use is relatively high on commercial crops (tea in Kenya, sugar in Mauritius and Reunion), but the threat to environmental pollution is negligible overall.

2. The reverse is in fact the case. The *absence* of input use, especially to maintain soil fertility and alleviate labor bottlenecks, is *causing* environmental degradation and affecting the quality and health of the human resource base as well.

3. The question of high- *versus* low-input technology is really a nonissue. The level and type of

Table 22.
Imports of Cereals in sub-Saharan Africa, 1963–67 and 1983–87 (in Thousands of Metric Tons)

Region	Wheat		Husked Rice		Maize		Millet/Sorghum		Total Cereals	
	1963–67	1983–87	1963–67	1983–87	1963–67	1983–87	1963–67	1983–87	1963–67	1983–87
West Africa	354,200	2,285,200	411,200	1,754,200	21,200	302,600	29,800	231,800	816,400	4,580,800
(% of total)	39.9	51.0	65.3	70.6	10.5	23.6	31.9	80.7	45.0	53.7
Central Africa	170,800	681,200	37,800	164,000	60,000	184,800	0	3,800	268.600	1,033,800
(% of total)	19.26	15.2	6.0	6.6	29.6	14.4	0	1.3	14.8	12.1
Eastern/Southern Africa	363,600	1,510,600	180,400	565,600	121,600	794,800	63,600	51,600	730,000	2,972,600
(% of total)	40.9	33.7	28.7	22.8	60.0	62.0	68.1	18.0	40.2	34.2
Total Sub-Saharan Africa	888,600	4,477,000	629,400	2,483,800	202,800	1,282,200	93,400	287,200	1,815,000	8,537,200
					Growth Rates (% per year)					
West Africa	9.8	9.8	4.5	10.6	11.8	16.7	12.6	9.1	7.7	10.4
Central Africa	6.2	8.2	6.0	9.3	10.2	1.8	0.0	0.0	7.1	6.8
Eastern/Southern Africa	6.2	8.6	6.2	5.5	7.0	12.7	3.3	–5.2	6.1	8.2
Total Sub-Saharan Africa	7.8	9.1	5.1	9.8	8.6	10.7	7.1	4.5	7.0	9.2

Source: USDA (1988).
Note: Total includes a small quantity of *other coarse grains* (e.g., barley).

inputs required should be determined by analysis of local circumstances (soil, climate, farming systems, and socioeconomic factors) rather than by slogans.

"Low-input agriculture" could simply mean farming systems where low levels of conventional inputs are applied, as in most of Africa today. But in recent years it has come to represent technology that makes very little or no use of agricultural chemicals, depending mainly on other means of increasing or maintaining current levels of production so as to avoid chemical pollution of the environment. While interest in such technology probably evolved mainly in the United States and Europe, it is increasing in developing countries. This is partly as a result of difficulties in persuading small farmers in risk-prone environments to adopt technology involving the use of cash inputs and partly due to concerns about chemical pollution, mainly on the part of donor agencies.

Management systems, such as integrated pest management, that reduce the use of cash inputs, especially chemicals, show promise for pest control in cotton and rice in India and Indonesia. But these systems require careful orchestration of physical, biological, and chemical inputs, often with very precise timing. So even if they are less costly in cash terms, they may be more demanding of labor and skills than the simple application of chemicals. Moreover, effective mechanisms for input production and distribution may be essential to their functioning (even when those inputs are biologically rather than chemically based), and this may put a new strain on overloaded government institutions.

There are also promising "organic" approaches to improving soil fertility, such as using algae, azotobacter, and mycorrhiza, although this is more relevant to paddy rice production. Animal manure is often a scarce resource and has competing uses for fuel, while green manure is usually rejected by farmers because it yields no measurable cash return and competes with cash crops for land, labor, and other resources. For maintenance of soil fertility, leguminous trees and annual grain and forage legumes have the most potential; however, under African conditions, where improved organic-matter content is crucial, a combination of organic farming with chemical fertilizer and trash mulching seems desirable. Labor constraints may limit the widespread use of this technology.

So while the potential of such systems should not be ignored, they are not necessarily a panacea for the rejuvenation of agricultural technology, nor is low-input technology alone likely to provide food security, let alone food self-sufficiency to most African countries. Considerable scope remains for improvement in the use of conventional inputs, especially fertilizers and herbicides. In many cases, unresponsive varieties are the main problem.

Thus, it makes sense to allocate inputs according to the technical and economic potential for their use. Selecting the right targets for research should take into account the crops on which they will be used, current levels of use, responses to those levels, their costs and availability, and the incremental returns to higher levels of use that have been indicated experimentally. The generally low levels of input use and the difficulty of establishing any clear correlation with ecology or population density suggest that a lot more research needs to be done on technology adoption (or the lack of it) and the underlying reasons. This will place demands on research and extension resources, and it will require a strong commitment by NARS to support research with a regional (agroecological zone) and farming systems perspective as well as to carrying out work on farms and with farmers. This commitment is not yet clearly evident in some NARS.

Alleviating Constraints to the Adoption of New Technology in Rain-Fed Farming Systems

Assuming that a supportive policy environment can be created as a result of enlightened national policies towards agriculture, the two principal factors hampering technological change in rain-fed areas of Africa would be low labor productivity and high risk due to drought and weather variability. No single action or component technology is going to remove these two constraints, but their progressive alleviation, within the overall national framework of agroecological zones and commodity priorities, should be the major research objective.

This is likely to involve applied research targeted to specific problems, coupled with on-farm and farming systems research to identify those problems for on-station scientists. There should also be a mechanism to incorporate the components into more productive forms of land use appropriate to

local agroecological conditions and farmers' needs and constraints.

The following areas of research would contribute to this objective:

1. **Developing more diverse farming patterns.** This could provide greater insurance against drought, increase soil fertility without long fallow periods, diversify the family diet, even out labor requirements, and provide additional products for sale. So far the prospects look best in more humid areas where annual/perennial crop, crop/livestock, or crop/livestock/tree-crop systems could be used. Okigbo (1990) postulates six alternative systems of farming to bush fallow in West Africa. However, some successes are also being reported from drier areas, e.g., in Niger with tree–annual-crop systems, windbreaks, etc. This will not be a simple or short-term process, but it has great potential.

2. **Closer crop-livestock integration.** Three possibilities for closer crop-livestock integration exist: (a) integration of crops and animals on individual holdings, (b) group holding and management of animals, possibly with professional staff, or (c) stratification between range rearing and fattening on arable farms or in feedlots. The first of these probably offers the greatest benefits in more favorable ecozones, where tsetse flies do not exist, provided that the farmer can grow enough feed. Manure is valued by African farmers, milk has a cash or dietary value, and the additional labor supplied by draft animals may allow the area cropped in a year to be extended and improve the timeliness of planting or weeding.

   In the drier Sahel, about 50% of farm incomes is earned from livestock that are moved to seasonal pastures — clearly a major form of drought insurance, but the animals are not kept mainly for work. Range improvement schemes seem largely to have been abandoned there. Further study is needed to reduce losses in abnormally dry years and to encourage fattening of animals off the range on better feed regimes — rather than walking them half-starved for long distances to slaughter. This might also alleviate pressure on the range and permit its regeneration.

3. **Improving timeliness of operations.** Most African experts see this as having considerable potential for increasing productivity without high input use, while at the same time, helping to reduce vulnerability to weather, but labor bottlenecks require farmers to make compromises among crops and to accept tradeoffs. The use of oxen for soil preparation is helpful, but weeding often remains a constraint, and so far herbicides have not been widely accepted, perhaps because of the prevalence of mixed cropping systems. Research should focus on new ways of alleviating these bottlenecks.

4. **Strengthening research on plant-soil-water relationships.** Enhancing the organic-matter content of soil helps improve moisture retention as well as nutrient status. Restoring macro- and micro-nutrient deficiencies through fertilizer is also a critical need, since anything that limits plant growth weakens stress resistance. However, crops and cultivars differ widely in their physiological responses to changes in soil-water relationships, with respect to both physical factors and nutrient status. One of the most important tasks is to understand the adaptation of plants and animals to the environments and the production systems in which they are produced. Whatever the environment, different crops have different economic potential at different stages in their life cycle.

   The crops that a farmer can grow have to make the best possible use of the time available between the sowing date and the end of the growing season, dates that are usually determined by when the rains begin and end. The kind of work that is directed to understanding these relationships has an important bearing on the development of improved crop varieties and the improvement of production systems. In rain-fed environments, the aim is to make the fullest possible use of the time when the risk of drought is least. This is why it is particularly important in the rain-fed agricultural systems that predominate in Africa to understand the variations in seasonal changes in the water balance. Only when this has been done, and the risk of encountering drought has been diminished as far as possible, is it worth searching for mechanisms of drought resistance in crop plants.

Research in this field is demanding on scientific skills and equipment. Yet this is a particularly weak area in sub-Saharan Africa, both with respect to university curricula and scientific cadres in the NARS. Improving the capacity to expand research in this field should be an important goal for human resource development in the 1990s.

5. **Introducing new crops to Africa.** The options include introduction of exotic cultivated species (including trees) unfamiliar to African farmers; new uses for indigenous species, including wild species; and the creation of new species for specific needs by breeding, as was the case with triticale. This should be regarded as a worthwhile but speculative longer-term objective.

Reinforcing Research on Storage and Processing

Storage, processing, and other aspects of post-harvest technology have received limited attention in international and national agricultural research programs in developing countries. In Africa, the total scientific resources devoted to research in this field in the mid-1980s were only 6% of those allocated to crop improvement.

This situation may be due in part to poor and sometimes conflicting data on storage losses. Although some published estimates show these as large, it is not always clear what proportion could be prevented, even by relatively sophisticated techniques. Moreover, this is often seen as a field in which the main responsibility should rest either with the private sector or with bilateral agencies because developed countries have a long history of expertise on post-harvest technology. Research directed to increasing production is therefore viewed as being of greater direct value, especially when the potential for making substantial progress in raising productivity appears good.

Given the slow progress being made in raising crop yields and labor productivity, and the low levels of commercialization in Africa, this seems to be an appropriate time to reinforce research into storage and food technology, especially at the farm and local level.

NARS should give a higher priority to studying farmers' traditional methods of food storage and processing. This could identify the main causes of losses. It could also determine whether techniques already exist that could be improved on or more widely applied. Suitable fields for research include the following:

- Innovative methods of food storage and preservation for low-potential or remote areas, where raising crop and livestock yields is difficult — any losses saved in these areas, which also tend to suffer from highly variable weather patterns, would be a contribution to food security and sustainability.

- Commercial market requirements (including export markets) for produce from higher-potential rain-fed areas and irrigated land — often NARS devote substantial research resources to the production of horticultural crops, oilseeds, and new crop introductions, but almost no studies are undertaken of the nature of market demand, quality standards, transportation, storage requirements, or processing possibilities. This frustrates producers and leads to project failure.

- Simple techniques for preparing new products from existing staple crops, in order to diversify rural diets and reduce food imports to urban areas — starchy products (especially cassava and plantains), cereals, oilseeds, fruit juices, herbs, and milk products are contenders. This could help create additional demand, stabilize prices at peak production periods, and generate employment.

- Simple, energy-efficient, cheap cooking devices — designing such devices would reduce fuelwood consumption, improve food preparation, and raise women's labour productivity.

Particular importance is attached to improving the storage life, quality, and processing of roots and tubers. Plantains and other fruits, which are primarily consumed in rural areas, are of great significance in the diets of the poor, and their cultivation is often a main responsibility of women.

Roots and tubers make up a large share of the diet in the more humid zones. They contribute double the amount of energy found in cereals, and in fact, cassava is grown and consumed widely throughout

most of Africa, not just in the humid areas. A major disadvantage to the wider consumption of roots and tubers is that because of their high water content, they are extremely perishable once harvested. This also makes them costly and difficult to transport. Data from an African workshop on marketing of starchy produce (FAO 1985) show that post-harvest losses range from 10% to 51% of production, depending on the country and the crop.

Pearce (1990) notes that most governments lack a policy framework concerning starchy crops and that they rarely attempt to influence their production or consumption, regarding them in effect as an inferior good. When foreign exchange is available, it may be easier for governments to fill gaps in the food supply with imported cereals. However, it is clear from the data cited in tables 19 and 20 that it is a serious error to view starchy crops as inferior. Given their ecological plasticity and yield potential, they could play a larger part in future diets than they do today, especially if storage and distribution problems can be alleviated.

Although it may be possible to improve the storage life of starchy crops and reduce the labor needed for production and processing by genetic means, this should not be the only approach to reducing storage and processing losses. The same applies to fruits and vegetables. *Considerable near-term progress seems possible through a concentrated effort to improve local storage techniques.*

It is encouraging to note that IITA (1990) has established active root-crop networks in West Africa (seven countries) and Eastern and Southern Africa (six countries) involving genetic improvement, biological pest control, on-farm testing and information gathering, and screening for taste, quality, storage, and processing characteristics. Work on food technology, processing, and quality of several crops, including some export crops, is being undertaken jointly in collaboration with African countries by CIRAD (France) and ODA (UK).

Research on Technology Transfer

Evaluating Different Approaches to Extension

There are wide areas of disagreement among proponents of different methods of extension. Many practitioners in this field are concerned about the cost-effectiveness of conventional extension systems which depend largely on direct contacts between field-level government staff and individual farmers or "farmer-leaders."

While there is a lively debate under way, with numerous ideas being proposed for improving the operational value and economic viability of extension systems, there is no general consensus as to the optimum approach. Indeed, no single answer may be possible. There may well be "different horses for different courses," with the optimum conditions for one approach or another having to be worked out and verified by research.

Much the same may apply to the adoption of improved technology by farmers. Why some adopt and others, in apparently comparable situations, do not is often a mystery. Moreover, African farmers, who are not unwilling to adopt when *they* see a benefit to their welfare, often confound the expectations of project staff by not taking up some innovation which seemed entirely rational and desirable to the planners.

These uncertainties suggest that there is an important need for further research into extension methodology and the best means of transferring technology. This research could also be enhanced if it were linked to adoption studies in which extension staff and farmers participated.

Unfortunately, most NARS devote very slender resources to research on technology transfer or to adoption studies or impact evaluation. And most African universities, unlike agricultural universities in some other countries, do not make extension technology or extension education a major element of their teaching programs. This indicates that progress on this type of research will initially be slow, requiring the relevant disciplines to be given highest priority in human resource development.

Increasing Opportunities for Women's Participation in Agricultural Production

Because women play such an important role in Africa as managers of farms, more attention should be given to the possible impact of technology on women's income and the use of their time. Some innovations may work against their interests, but others can enhance them. It is important for research and extension staff to be aware of the role of women in farming, which activities benefit them or are their prerogative, and where their cooperation could lead to greater progress. Research and extension should cover the role of women in production, storage, and marketing, as well as in family health and nutrition, since the two roles are closely interwoven and both compete for their time and energy. Women may need advice and assistance from government staff, both as farm managers and housewives. However, the government representative may not be suited to both tasks; hence, the fallacy of concentrating on government services to women mainly in the field of home economics. Thus, research is also needed on how improved technology for production and marketing can most effectively be transferred to women.

Institutionalizing Impact Evaluation as an Integral Component of Research and Technology-Transfer Systems

More effective and timely evaluation of the social and economic impact of new technology (whether positive or not) could provide a great deal of invaluable information to planners, not just on the performance of the components of the technology-transfer system, but also on farmers' attitudes and problems, and on the constraints imposed on their acceptance of new technology. Thus, it would be extremely valuable to the formulation of national agricultural policy as well as research and extension policy (World Bank 1990).

Experience by some donor agencies (for example, USAID and GTZ [Germany]) suggests that farmers should be involved more closely in planning projects or programs aimed at developing and introducing new technology. This involvement should also provide for evaluation of the project during its formulation, which would greatly facilitate ex post impact analysis. Evaluation of ongoing projects would help by contributing to mid-term corrections, while analysis of completed projects could help avoid errors in developing new ventures. USAID is currently developing a manual for impact analysis.

Nevertheless, systematic evaluation of the social and economic impact of research and technology-transfer activities is not normally an institutionalized component of research or extension systems. Evaluation is often confused with routine monitoring of ongoing activities, and benefits may simply be expressed in terms of numbers of varieties released or extension visits undertaken.

In fact, impact analysis is complex, time-consuming, and demanding. There are difficult methodological problems involved in assessing and attributing benefits. The benefits need to be assessed against the expectations of the original program or plan, and against baseline data collected at its inception. The analysis may have to be repeated over time to allow for time lags in adoption. A good deal of fieldwork, including case studies, may be needed. Yet the returns to well-conceived evaluation can be great. Action by development-assistance agencies to help countries build effective evaluation units should be a priority for the 1990s.

4

Action Priorities: An Agenda for the 1990s

Reinforcing Research on Food-Security Policy

Successful food-security policy involves the integration and interaction of political decisions related to food production and consumption, trade and exchange rates, investment in infrastructure and institutions, natural resource management, social welfare, prices, subsidies, fiscal issues, and so on. It is a highly complex area of decision making, requiring judgments on trade-offs between food imports and domestic production, rural and urban populations, allocation of scarce resources, especially hard currency, among competing sectors, and numerous other difficult problems.

We have noted repeatedly in this paper that government policies are crucial to the generation, transfer, and successful adoption of improved agricultural technology by African farmers, and this does not need to be discussed in further detail here.

We also argued in an earlier section that a strong capability for policy research is essential to provide information and guidance to national planners in formulating decisions related to food security. We pointed out some major constraints affecting the national capacity to address research on food-security policy, and we drew attention to the need to increase the capability for policy analysis among staff in the NARS. This is important for two reasons. It will enable NARS management to work with government planners in developing a national *research* strategy, and it will allow the research system to address wider policy issues affecting food security and to provide an input to national policy on these matters. Training NARS staff in economics and social sciences should receive high priority in human resource development. At present these disciplines only represent about 5% of the researchers in Africa. This, however, is a longer-term goal, and it may require that the capability to teach in these disciplines be strengthened at the universities.

Meanwhile, other measures should be urgently explored to strengthen the capability to conduct research on agricultural policy. Probably the most effective approach would be to develop regional research networks on food-security policy, perhaps with regional meetings to provide a wider pan-African forum on key issues and an interlinking mechanism to encourage information exchange.

> *One important aim of such an effort should be to identify the policies and conditions required to provide a supportive environment—one that would facilitate the adoption of improved technology without creating serious distortions in the economy as a whole.*

Such networks could be sponsored by regional organizations, such as SACCAR or CILSS, or by groups of universities with support from donors or from SPAAR where no appropriate regional sponsor exists. National planners, economists, and social scientists from the NARS and universities could participate in these networks. IARCs, such as IFPRI, which has a strong policy research capacity, or

IITA, could collaborate with the networks both at the macro- and micro-level. A strong internationally supported policy research network involving IARCs, NARS, and universities in Africa is an essential component of a forward-looking food security effort for the 1990s.

Raising the Productivity of National Agricultural Research Systems

Africa had a late start in developing indigenous research and technology-transfer systems, and institution-building will remain of high priority through the 1990s. Some NARS are still so weak numerically that they can hardly do adaptive research. To the extent that they can be sustained once donor support is withdrawn (although most NARS are likely to remain dependent on external assistance for some years to come), these small systems need to be expanded, perhaps to the level of 100 scientists suggested by Rocheteau et al. (1988). ISNAR, with support from Italy and Denmark, has recently launched an initiative to create a reliable and up-to-date data base on small-country NARS and their agricultural research needs. This will serve as a basis for suggesting management strategies and organizational models and mechanisms appropriate to the specific needs of small-country NARS (see also Eyzaguirre 1991).

However, the time may be ripe for a change from a policy of merely increasing staff numbers to one of raising staff productivity. This may be particularly appropriate for larger systems. Suggested actions are listed below.

Sharpening the Focus of Research

- improve the link between research and policy and raise the capacity of the NARS to advise on agricultural development goals;
- develop a sound national agricultural research strategy with clear priorities for the allocation of resources to research;
- concentrate on a relatively small number of key food and export commodities.
- devote more effort to characterizing agroecological zones and allocate resources to zones and problems with high potential payoff;
- give greater emphasis to off-station research with extension staff and farmers and to working in areas of applied research to design technology specific to farmers' needs;
- create task forces for special research projects targeted at problem areas or disadvantaged groups;
- establish and institutionalize effective procedures for monitoring and impact evaluation.

Raising the Efficiency of Research

- wider use of modern techniques to increase precision or accelerate output — the following are examples:
  - provide personal computers and special software packages;
  - develop data base systems (such as CIRAD's crop-protection data bank);
  - use modelling and simulation in planning and projections;
  - access international information systems and establish national library or other facilities for screening, cataloguing, storing, and transmitting material.
  - apply remote-sensing and satellite imagery for resource assessment;
  - upgrade laboratory and screenhouse instrumentation capabilities for bioassay and biotechnology, soil and water analysis, climate and growth modelling, etc.;
  - provide adequate transportation and logistical support to outposted field staff.

Selective Training of Staff to Strengthen Critical Areas of Weakness

- Develop a long-term (10-year) program to raise levels of competence (e.g., more staff with postgraduate qualifications);
- as part of this program, give priority to strengthening the capability to do research on commodities or disciplines of particular importance to

the long-term goals of national development policy. In most countries of sub-Saharan Africa research on the following needs to be strengthened:

- commodities — legumes, oilseeds, horticulture, animal management, agroforestry;
- disciplines — natural resource management, soil-plant-water relationships, food and post-harvest technology, policy analysis and social sciences, extension, and information science;
- management — both institutional (business) and research management;
- monitoring and evaluation techniques and procedures.

Providing Conditions of Service That Encourage Productive Research and Reward Performance Relevant to National Objectives

Two crucial requirements are (a) financial stability and sustainability and (b) sound financial and human resource management in the NARS. Factors that encourage productivity include the following:

- strong, stable government and donor commitment to financial support, including predictable levels of access to foreign exchange;
- prompt and full disbursement of budgeted funds to and within the system;
- enlightened career prospects and equal treatment of headquarters and field staff with respect to promotion, training, and other conditions of service.

The sustainability of many African NARS is a matter of concern, since donor funding currently makes up a very high proportion of their total budget. There is a need to find ways of ensuring that they can continue to exist without such heavy donor support. They also need to find ways of avoiding instability as a result of short-term variations in donor contributions or in exchange rates. Normally, there is no "donor of last resort" for NARS to fall back on, as is the case with the CGIAR system. One suggestion has been for a NARS to be given a one-time grant by donors, perhaps acting in consort, thereafter using the income earned from interest on that grant to provide long-term support to the system. Clearly, any such arrangement would depend on a clear definition of the use which the country concerned would make of the fund, as well as on demonstration of sound managerial capability and financial accountability. Nevertheless, it may be an option worth exploring as an alternative to current relatively short-term financial grants to NARS from individual donors.

Modernizing Technology Transfer at the National Level

The continuing debate on how best to communicate new knowledge and materials to farmers suggests that much remains to be done to develop more effective ways of transferring technology. This debate has also included questions about the relative lack of progress that has been made in raising yields and combating environmental degradation, even in higher-potential areas.

There are two main requirements for developing more effective ways of transferring technology: (a) determine which systems of communicating new knowledge to farmers are most appropriate to different national situations and (b) equip extension staff in existing systems in a way that will enable them to perform their tasks in the most cost-effective fashion.

With respect to the first requirement, comparative analysis of different approaches to technology transfer must be done. Various systems in current use in Africa include the following:

- conventional hierarchical approaches, such as the T&V system, which employ large numbers of field staff with relatively low levels of education and training, who work in direct contact with farmers and are supported by subject-matter specialists.
- group-oriented or cooperative organizations that provide advice to farmers, sometimes with input and other services;
- profit-oriented agencies that provide vertically integrated specialist services to growers of certain high-value crops where the costs can be recouped by a tax.

- devices such as graduate extension-liaison units to improve research-extension-farmer linkages.

Much more needs to be learned about the circumstances under which extension services might be most effective in African countries (i.e., farmer density, type of farming and farming systems, infrastructure, educational levels of farmers, etc.), as well as about the costs of these services and the ways in which such costs might be recovered. Looking ahead, it is conceivable that smaller but better-trained, better-equipped, and more mobile services, might be more in line with future needs than conventional T&V-type approaches.

In order to shed light on this important issue, it is worth considering whether one or two countries could be assisted to act as "guinea pigs" for a comparison of various approaches to technology transfer within their borders. Perhaps this could be done as a pilot project, with donor assistance, to study the cost and effectiveness of the different approaches. Alternatively, cross-country analysis might be undertaken across a group of comparable countries. This might be suited to a network operation, involving NARS with an IARC or a regional research institution, supported by SPAAR or a regional organization such as SACCAR.

Measures to improve the efficiency of existing technology-transfer systems include the following:

- Wider use of media and audiovisual presentations — it seems unlikely that conventional approaches involving direct contacts between extension agents and farmers or groups of farmers will be superseded by other methods of mass communication within the space of the next decade. However, there are opportunities for implementing and enhancing field agents' work as well as extending their coverage by the use of such methods.

  These methods include radio programs, television, and particularly, the use of videocassettes, which, after training, can be produced by local staff using real-life examples to compelling advantage. Tapes and videos can be used to bridge language gaps, reach disadvantaged people, and communicate information to remote villages. Timing and topical relevance is critical to the value of radio and television programs.

  Interactive video/computer systems can help in training extension staff. They can also be useful for refining advisory recommendations in cooperation with farmers. They can be used to improve feedback to researchers or even to influence policymakers by enlightening them about local problems, providing evidence of successful technology transfer, or informing them of farmers' views on the consequences of policy decisions.

- Information collection and exchange — most countries operate some kind of technology-transfer system, but there is often little awareness in one country of what goes on in the others. This is an area in which international or regional action would be valuable. It could promote information exchange and contacts among developing countries and could establish an institutional memory concerning the experiences and innovations of the countries involved. There is a fund of existing knowledge that could be drawn on to accelerate progress in both research and technology transfer. This knowledge needs to be accessed, if possible, with its originators, before it is lost. It should be inventoried, checked, stored, and made widely available — which would be a useful project for support from a donor group like SPAAR or, on a regional basis, by organizations such as SACCAR or Club du Sahel.

- Training — it is clear from recent reviews of extension in Africa that serious constraints are caused by weaknesses in staff training. Priorities identified for special attention include the following:

  - managerial skills (as with research there is a critical shortage of staff with training in systems, finance, and personnel management);
  - more and better-trained subject-matter specialists;
  - impact evaluation, requiring advanced skills and interdisciplinary teamwork;
  - information science and communications technology, including operation and maintenance of modern word-processing, computer, and audiovisual equipment.

Improving Access to Key Production Inputs

The three key inputs on which the Green Revolution was founded were (a) improved, high-yield cultivars, (b) fertilizer, and (c) water. It is arguable that one of the main reasons for the failure of the Green Revolution in most of sub-Saharan Africa has been the limited access that most African farmers have to those inputs.

The reasons for this are discussed in earlier sections of this report. If the ambitious growth rate in food production indicated in chapter 1 is to be approached by the year 2000, these problems must be addressed now. The seed and fertilizer issues can be approached more readily in the short to medium term than can those of improving plant-water relationships. But measures to alleviate water constraints cannot be ignored: it is one of the main reasons that the adoption of other production inputs has been limited.

Strengthening Seed Production and Development

We noted earlier that a farmer's willingness to adopt new crop varieties is often frustrated by inadequacies in seed supply — high cost, insufficient quantity, poor quality, and sometimes a combination of all three.

This is a situation that should not be allowed to persist, since good seed of productive varieties is the simplest (and should be among the least expensive) of all the means to production.

In some cases, research is needed to overcome local problems with diseases or quality, to accelerate the availability of improved genetic material (for example through tissue culture), to solve problems involving cross-pollinated crops such as millet, or to overcome storage problems (as with cowpeas or roots and tubers). But most of the technical problems likely to be encountered in seed production are fairly well known and studied, and routine seed production, multiplication, and distribution is not normally a research function, nor is it the most productive use of a researcher's time.

When NARS become aware that seed has become a bottleneck to the use of their research, their task should be to determine whether further research is needed to overcome the problem, or whether the solution really lies in the absence or ineffectiveness of seed production facilities. In Africa, where the commercial sector is often weak, the government may have to take the main responsibility for seed production as well as for quality control where commercial producers exist. In addition to developing breeders' seed, the research staff may help with advice on specific problems. FAO has been giving priority to strengthening seed production systems and could be called on for assistance.

Seed production can be a fruitful field for regional or even interregional cooperation, with different countries complementing each other in producing seed of different crops and cultivars, as has been the case in Southern and Eastern Africa.

A potential problem with supranational arrangements is the appropriateness of varieties developed in one country to requirements for the same crop in other countries. In chapter 1, we commented on the frequent rejection of apparently promising new varieties by farmers. This suggests that any commitment to produce seed by one country for sale to another country should be preceded by very thorough adaptive testing in that other country.

Seed treatment has been shown to offer cheap and fairly effective control of certain root diseases that affect a plant's water intake, as well as control of head smuts and other seed-borne diseases in Africa. It is being adopted by some farmers, and it should be encouraged by extension services, especially where purchased seed is being used.

Expanding the Use of Fertilizers on Food Crops

Lack of plant nutrients is probably the single most important factor limiting food production in Africa. Fertilizer is the key input to increase food production, although organic matter and nitrogen from leguminous crops in rotation also contribute.

The main constraints to increased fertilizer use are high price and lack of timely availability of the appropriate formulation. Both of these problems are related to poor infrastructure and input distribution networks, often compounded with very long distances between sources of material and users. It is frustrating to note the frequent references to the African farmer's unwillingness to apply fertilizer

because it is not economical, even when crop responses are large by standards in other regions.

Measures to reduce costs may include the development of more concentrated compound formulations, the treatment of local rock phosphate to improve its uptake by plants and to make it easier to handle, and shipment of fertilizer in bulk to local distribution points where it can then be broken down into small bags for further distribution. The development of fertilizer-responsive varieties is an essential, but complementary, approach to improving cost-effectiveness.

Nevertheless, the single most effective inducement to increased use of fertilizers seems likely to be a reduction in its direct cost to the farmer. The use of subsidies appears to run counter to the tenets of structural adjustment, but national policymakers and development-assistance agencies must seriously consider whether it is more acceptable to subsidize some elements of fertilizer costs (or costs of transport) now, rather than suffering the long-term consequences of having to import huge quantities of food by the end of this century. In some countries, governments appear to have reduced fertilizer imports because of shortages of foreign exchange due to their debt burden and the declining world prices for their exports. In such cases decision makers need to question whether fertilizer is the appropriate target for economic cutbacks.

Alleviating Water Constraints to Crop and Animal Production

While it must be faced that most farmers in Africa will continue to depend primarily on rainfall during the remainder of this century and beyond, this does not mean that nothing can be done to alleviate the constraints imposed by drought or by excess rainfall. A number of measures directed to this end are discussed in chapter 3, and three of these are suggested as priorities for action:

1. **Better understanding of plant-soil-water relationships.** This implies applied and possibly strategic research, with IARCs, NARS, and universities collaborating. It is currently relatively weak — there are approximately five times as many scientists working on crop improvement as on disciplines related to natural resource management. Benefits could involve improved agronomic practices to reduce drought vulnerability or to avoid it, guidance for plant breeders on desirable varietal characteristics related to water use, and changes in farming systems to optimize water availability.

2. **Improving genetic resistance to stress.** Again, this is an area where several disciplines need to be involved and where strategic and applied research may be required. Some stress factors, particularly drought, involve multigene complexes, but others, which weaken plant resistance to drought stress, may be easier to tackle by breeding. These include certain widespread pests and diseases such as rice blast, cassava mosaic, and sorghum-shoot fly, which are already the subject of work by IARCs in Africa. We have suggested that parasitic weeds of cereals, Striga in particular, also merit international priority for research. In the case of ruminant livestock, especially cattle, the importance of reducing the incidence of trypanosomiasis has been stressed. Control of tsetse flies, genetic resistance to the disease, and development of a vaccine are all being pursued; this is another challenge of international significance.

   This is an area where biotechnology appears to be a useful tool, both with its more sophisticated aspects, such as DNA transfer, and through tissue culture and other techniques to speed up the production and distribution of disease-free vegetative material.[9] However, where its use results in new interspecies hybrids or other wide crosses, a long period of refinement using conventional breeding and selection methods is likely before a commercial product can be available. To the extent that private industry is involved, intellectual property rights and other legal hurdles may have to be overcome. Instant miracles should not be anticipated!

3. **Development of small-scale irrigation facilities.** The potential for medium- to large-scale irrigation in Africa appears to be good; however, extremely high costs per hectare and relatively low returns from irrigation compared to rain-fed agriculture have discouraged new investments in irrigation projects.

9. USAID has recently announced a three-year grant to the Monsanto Corporation to train two African scientists in the United States in state-of-the-art research to develop genetically engineered resistance to viruses in key root and tuber crops.

On the other hand, there appears to be considerable scope for the development of low-cost, small-scale irrigation systems in valleys where streams or springs, or simply a high groundwater table, are the source of water and where soils are reasonably fertile. In Southern Africa these small-scale systems are known as *dambos*, from a Zambian word. Their total area has been estimated to cover 80 million hectares, and where they have been developed by local farmers, they are often very productive. Supplied by simple water-lifting devices, they usually involve rice in the valley bottom and other annual and perennial crops around the perimeter.

Their main potential is in the humid and subhumid areas of Africa, and a masterplan to survey the opportunities, approaches, and likely costs of their systematic development should be drawn up. This would require an internationally funded effort, based on modern survey techniques. In the semi-arid and arid regions, groundwater surveys for tube-well irrigation and for drinking purposes deserves higher priority.

Understanding the Ecological Potential of Africa

In recent years, the environmental approach (agroecological characterization, mapping, and the development of related data bases and geographical information systems) has become recognized as a valuable tool for understanding the nature and dynamics of agricultural environments, defining actual and potential land use, identifying location-specific research priorities and appropriate research sites, and extrapolating research results among different geographical regions by establishing agroclimatic analogies. One important goal of this work has been to exploit spillover of research results, which is of particular interest to countries with small NARS but which have the capability to test borrowed technology and adapt it to their own needs.

Characterization of environments and defining current and potential land use also provide a basis for responding to climatic change — through analysis of changes in weather patterns and through ex ante projections, including simulation and modelling. The environmental approach also makes it easier to monitor environmental pollution and degradation resulting from deforestation, overgrazing, crop mismanagement (especially in marginal areas), and other human activities. It will also make it easier to differentiate between areas of high and low potential, as well as between levels of demographic pressures, as a basis for targeting research.

This environmental approach is being used as a basic tool for defining international research priorities by the Technical Advisory Committee to the CGIAR system, by ACIAR, and on an increasing scale, by the IARCs. However, it is not yet being widely used by NARS. This is probably because the processes of data collection, recording, analysis, and mapping are quite resource-intensive, and there is a relative scarcity of personnel experienced in the various disciplines required, especially within NARS. Even at the IARCs, the staff working in this area is small and their role with the NARS is essentially catalytic.

Funding will be needed for training, for establishing and equipping weather stations, and for purchasing computers, operational equipment, and vehicles. The potential value of this work to international and national research, as well as to sound and sustainable national agricultural development policy, merits strong support from donors.

It is therefore encouraging to note that UNEP is sponsoring a second meeting of the International Agricultural Research Centers on the subject in early 1991, and that France, the Netherlands, and the United Kingdom are supporting research and training in this field to assist developing countries. SACCAR is supporting two regional projects under its food-security administration for work on agroecological characterization. FAO has pioneered work in agroecological characterization and should be able to assist African countries in the methodology and its application.

This is regarded as a priority of long-term international importance. The benefits will be progressive and cumulative and will greatly assist prospective planning and targeting of research. Also, recognition of its potential is relatively recent and the methodology is still evolving, both in terms of the techniques of agroecological characterization and classification, and in linking this to spatial socioeconomic analysis.

International and Regional Cooperation in Research and Technology Transfer

A number of opportunities for international and regional cooperation with NARS in Africa have already been identified in this chapter (with respect, for example, to policy research on important issues of food security). Here we address some of the institutional mechanisms that might enable them to be followed up.

Africa has more NARS than any other developing region, and many of them are rather small, which affects both their capacity to work on their own problems and their ability to participate effectively in collaborative efforts with IARCs or other African countries, and with donors.

USAID, for example, has adopted the pragmatic approach of categorizing national systems according to whether they have technology-generating or technology-adapting programs, according to their capacity to do applied or mainly adaptive research, and according to the type of assistance they can use most effectively.

The larger systems may have relatively sophisticated facilities and can collaborate directly in research with IARCs or other national systems. However, the issue with small countries is how to provide them with access to at least some of the know-how and equipment available to larger systems, thus helping them achieve the benefits of economies of scale and critical mass.

This issue is being approached in Africa, largely through intercountry cooperative research networks. In some cases, these are problem- or commodity-based networks across Africa. In others, they are implemented through regional groupings (CILSS, SACCAR, etc.). In many cases, one or more of the international centers is involved, often as a "lead agency," and there may be one or more donor supporters. One of the most important effects of these networks is that they maximize spillover of knowledge, materials, and technology among the cooperating countries.

Regional cooperation in research may take one of two forms: NARS may work together to aggregate their resources so as to achieve scale to work on common problems, especially where there are broad agroecological similarities. Cooperation among the Sahelian countries is one example of this. Alternatively, countries may agree to work individually, according to a common plan, on problems that maximize their comparative advantage and regional complementarities. This is the case with the SACCAR region. Both types of cooperation can augment the work of a NARS, but they are not a substitute for building national research capability.

There are valuable opportunities for strengthening linkages through networking (e.g., between disciplines, between IARCs and national institutions, with universities, etc.), and these are likely to have a lasting impact on the national researchers involved, even after the network has served its immediate purpose. Thus, they play an important institution-building role. Networking also helps the IARCs use their limited resources more effectively: they are able to develop research contacts on important problems with several countries without having to disperse individual staff members to do adaptive research in every country of Africa.

Nevertheless, some dangers exist with networks. They have tended to proliferate in Africa, running the risk of overloading national systems and thus defeating their objectives. At a recent meeting in Africa, it was pointed out by a participant that some countries lack the staff, funds, and research facilities to benefit fully from participating in networks. Large discrepancies between the participants' levels of scientific training must be avoided. Prior to the establishment of the networks, the potential users need to be consulted fully as to their objectives and who will participate. Regional organizations can play a valuable role in planning networks. Sponsors need to consider these factors carefully, as well as the levels of resources needed to operate the networks successfully. A review of the SPAAR experience in trying to coordinate donor activities in Africa would be valuable.

In addition to direct institutional support of African NARS and of networking, there are a number of ways in which IARCs and donors can foster research collaboration with NARS. These include methodological support in planning or analysis of research, high-tech backstopping of research being undertaken by NARS (the CIRAD biomodels and PANTROP software system are examples, as are the IBPGR and IARC germplasm banks). Direct collab-

oration between developing- and developed-country institutions in research where the two may complement one another is increasingly common — some donors have set up special organizations in parallel with their development-assistance agency to facilitate this. These include Australia (ACIAR), Canada (IDRC), Sweden (SAREC), and France (CIRAD).

More experimentation with institutional mechanisms is likely to be feasible and desirable as national systems become more sophisticated. This will be especially true with respect to research planning and coordination, strategic research and biotechnology, exploiting the potential of new hardware and software, and transmitting research results to users through the use of modern communication techniques by extension services. We noted above the need for comparative analysis and evaluation of national technology-transfer systems in Africa, and this could be an important subject for a regionally supported program.

In conclusion, it must be emphasized that two key objectives need to be pursued during the present decade to increase the effectiveness of research and technology transfer oriented towards food security in Africa:

1. The responsible national institutions must be strengthened and their sustainability ensured. This is a long-term challenge to be pursued by governments and donors in concert.

2. The absorptive capacity of national governments and institutions has been seriously burdened by the vast and choatic array of direct and indirect donor assistance and other interventions (referred to in chapter 2). Ways of reducing this burden must be found in the near term, as must ways of raising the benefits of these interventions to the recipient countries relative to their costs.

The establishment of SPAAR was a hopeful, if belated, attempt to improve the coordination and focus of donor support to agricultural research in Africa, but its evolution suggests that it faces a very difficult task. Regional initiatives, particularly SADCC/SACCAR are promising, but such organizations do not cover all the geoclimatic regions of Africa. The World Food Council appears to be an appropriate international organization to address this thorny but crucial problem and to devise appropriate means of alleviating it.

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