9

The Technological Foundation of the Revolution

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The foundation for renewed growth in Africa's agricultural sector is investment in cost-effective, relevant research and extension systems that can generate rapid and broadly based technical change in staple food crops, including maize. The development of such systems is a long process, however, and focused research efforts on food crops, especially for smallholders, are a recent undertaking in most African countries. This chapter reviews the achievements of Africa's research and extension systems with respect to smallholder maize production and examines the challenges that remain to be addressed. We first summarize evidence on the adoption of maize technology, particularly improved seed, and discuss the technological constraints on increased maize production in Africa. Next, we review the progress that has been made over the past two decades in building research and extension systems. We conclude by discussing ways of fostering a research and development (R&D) capacity that will keep new technologies flowing to Africa's extension workers and small-scale farmers in the decades to come.

Evolution of Maize Research Programs in Africa

Maize research began in colonial times in Africa and focused mostly on improving maize for large-scale European farmers. Work on hybrid maize was initiated in 1932 in Zimbabwe; Kenya followed in 1955. Zaire and a few other countries established maize research programs for smallholders in the 1930s, but these efforts remained fairly modest until recently in most African countries in relation to research on cash crops and research for commercial farmers (Miracle 1966). At independence in 1960, research systems were generally small, and 90% of the researchers in Africa were still expatriates (Pardey, Roseboom, and Anderson 1991). Moreover, few scientists had training in, experience with, or orientation to smallholder agriculture.

In the decades since independence, investment in public national agricultural research systems (NARSs) has expanded more than fourfold (Pardey, Roseboom, and Beintema 1997). Expansion was particularly rapid until 1980, but research budgets have stagnated or declined ever since. The number of scientists has continued to rise, however, resulting in a sharply reduced expenditure per scientist (Pardey, Roseboom, and Beintema 1997).[1] Data from a 1991 survey show that about 272 maize scientists worked in public-sector maize research programs in Africa, and an additional 31 worked in the private sector (Table 9.1). The intensity of maize research in Africa, measured in scientists per million tonnes of maize, is still less than that in other regions of the developing world. The fact that most African countries have several maize production environments in a relatively small maize area compounds this resource constraint.[2]

The national maize research effort in Africa has been complemented by the efforts of the international agricultural research centers (IARCs), such as the International Institute of Tropical Agriculture (IITA), which launched a maize research program in western Africa in 1970. The International Maize and Wheat Improvement Center (CIMMYT) initiated maize research in eastern and southern Africa in the late 1970s and established its regional maize research station in Zimbabwe in 1985. In the mid-1980s, the IARCs spent an estimated 43% of their U.S.$11 million maize research budget in Africa (Gryseels and Anderson 1991).

Table 9.1 Africa, Asia, and Latin America: A Comparison of Maize Research Resources and Varietal Releases, 1991

	Africa	Asia[a]	Latin America[a]
Number of countries surveyed	20	9	12
Maize area per country, 1989–1991 (million ha)	0.67	1.86	0.96
Number of maize megaenvironments per country[b]	5.4	5.7	4.4
Number of public-sector maize researchers			
Breeders	86	175	182
Nonbreeders	186	240	87
Percentage of public-sector researchers holding M.S. or Ph.D. degree	51	60	39
Number of private-sector maize researchers	31	125	108
Percentage of maize breeders in the private sector	27	42	37
Total number of public and private maize breeders per million t of maize	6.7	10.7	13.0
Number of maize varieties/hybrids released per million ha maize, 1966–1990	25	11	30

Source: CIMMYT maize impacts data, 1992.
Notes: a. Excludes Brazil and China, the two largest maize producers in the developing world. Maize is used mostly as a commercial crop for livestock feed in Brazil and China.
b. Breeding environments as defined by CIMMYT.

The Impact of Maize Research in Africa

Release and Diffusion of Improved Varieties

Maize research in Africa resulted in the release of over 300 improved varieties and hybrids by national maize research programs between 1966 and 1990. African farmers can now choose from about as many open-pollinated varieties (OPVs) and hybrids as farmers in other regions of the developing world (Table 9.1). The diversity of production environments in Africa, however, means that additional varieties still need to be developed for some agroecological niches (e.g., Hassan, forthcoming).

Although most countries have conducted maize breeding programs for at least 20 years, their success in delivering appropriate varieties and hybrids to a wide spectrum of small-scale farmers has varied. Improved maize is grown on as little as 20% of the maize area in Ethiopia and on nearly 100% of the area in Zimbabwe (Table 9.2). The relative emphasis on hybrids versus OPVs has varied as well, changing markedly from eastern and southern Africa to western and central Africa. The first breakthrough with hybrid maize for smallholders occurred in Kenya in the early 1970s (Gerhart 1975). By the mid-1970s, most small-scale farmers in Kenya's more favorable highland areas grew hybrids originally developed for commercial farmers. In the 1980s and 1990s, hybrids spread slowly to less favorable areas of the country (Hassan, forthcoming). Smallholders had similar success with hybrid maize in Zimbabwe, Lesotho, Swaziland, and Zambia in the 1980s and Malawi in the early 1990s. The use of hybrids in eastern and southern Africa reflects the fact that most maize research programs were established to serve commercial farmers.

In contrast, research in western and central Africa emphasized the development of improved OPVs of maize specifically tailored to smallholders' needs. Open-pollinated varieties are appealing as an appropriate technology for small-scale agriculture because farmers can save the seed from year to year. These varieties were rapidly adopted in the savanna of western Africa (Table 9.2), especially Nigeria and Ghana, as described in Chapters 7 and 8. Open-pollinated varieties are dominant in western and central Africa for two reasons. First, the tropical lowlands (usually defined as areas less than 900 m in altitude) constitute the major ecology for maize production in the region, and hybrids for this ecology became available only recently. Second, the main source of improved tropical germ plasm in this region has been the IARCs, which have bred mostly OPVs.

The overall record of adoption of improved maize varieties and hybrids in Africa is impressive. Almost half of the maize area in eastern and southern Africa and one-fifth of the area in western and central Africa is planted to improved OPVs and hybrids (Byerlee and Heisey 1996). The

Table 9.2 Sub-Saharan Africa: Maize Area Planted to Improved OPVs and Hybrids, 1990

Country	Total Maize Area (000 ha)	% Area Under Improved OPVs		% Area Under Hybrids	% Area Under OPVs and Hybrids	
		Minimum[a]	Maximum[a]		Minimum[a]	Maximum[a]
Tanzania	1,631	6	18	6	12	24
Nigeria	1,500	22	87	2	24	89
Kenya	1,500	8	8	62	70	70
Malawi	1,344	3	3	11	14	14
Zimbabwe	1,150	0	0	96	96	96
Ethiopia	1,050	8	24	5	13	29
Mozambique	1,015	17	17	1	18	18
Zambia	763	5	5	72	77	77
Côte d'Ivoire	691	14	42	4	18	46
Ghana	465	16	48	0	16	48
Benin	454	9	27	1	10	28
Uganda	389	30	70	10	40	80
Togo	296	7	18	3	10	21
Burkina Faso	216	15	70	2	17	72
Cameroon	200	20	67	1	21	68
Mali	170	36	50	0	36	50
Lesotho	145	12	12	70	82	82
Burundi	124	5	20	0	5	25
Senegal	117	100	100	0	100	100
Swaziland	84	0	0	90	90	90
Africa[b]	14,500	11	26	23	34	49

Source: CIMMYT maize impacts data.

Notes: a. Minimum = area usually based on seed sales; maximum = area based on surveys or breeders' estimates.

b. Excludes over 1 million ha of maize in Zaire, Angola, Somalia, and Namibia, which were not covered by the survey.

adoption of improved maize varieties and hybrids has progressed almost as quickly in Africa as in Asia and Latin America, especially if developing countries with large commercial or irrigated maize sectors are excluded (China, Argentina, and Brazil).

Despite these past successes, maize breeding programs have often taken insufficient account of the special circumstances of small-scale farmers when setting research priorities, resulting in low adoption. For example, smallholders in much of Africa plant maize late because of labor constraints, risk considerations, and crop rotations (Low and Waddington 1990). These farmers generally prefer maize varieties that mature earlier than the materials grown by commercial farmers. In other cases, farm households can improve their food security by planting early-maturing maize that can be consumed in the "hungry season" before the main harvest (Low 1988). Recent research has addressed this requirement, and early-maturing maize materials are being released and adopted in areas where they had previously been considered unnecessary. The productivity

of late-planted maize can also be increased through crop management practices for late-planted fields. In the past, agronomic research has focused on developing practices, such as fertilizer doses and timing of application, for fields planted at the optimum time (Low and Waddington 1990).

Maize breeding programs have also given insufficient attention to postharvest issues such as grain quality, storability, small-scale processing requirements, and consumer preferences. For instance, farmers in many areas of southern Africa prefer the harder flint maize varieties because they have much lower on-farm storage and processing losses than the available soft dent hybrids (Chapter 5). Increasingly, maize breeders are responding to these preferences. Matuba, an OPV recently released in Mozambique, has gained wide acceptance because its home consumption characteristics and the length of its growing cycle meet farmers' requirements (Sperling et al. 1995). However, since the cost of developing a variety increases with the number of selected traits emphasized in selection, however, research priorities must be selected carefully (Chapter 10).

Adoption of Improved Crop Management Practices

Even in countries where improved varieties cover much of the maize area, only modest yield gains have been achieved. Although the use of improved maize can be a catalyst for increasing farmers' use of other inputs, especially fertilizer (Smith and Goldsmith 1995), such broad-based change has occurred only in some parts of Africa. For example, maize area and yields expanded rapidly in the west African savanna following the release of suitable varieties and associated improvements in infrastructure and input supply (Chapter 8). But the more common experience has been that most farmers fail to adopt the additional production practices needed for sustained improvements in maize yields. This is particularly true of practices for maintaining and enhancing soil fertility, despite the fact that the demise of the bush-fallow system has made poor soil fertility the major constraint on maize productivity in much of Africa (Chapter 11).

Farmers grow improved varieties without fertilizer in many areas of Africa—especially in marginal areas, such as the drier zones of Kenya and Zimbabwe, but also in some relatively favored areas, such as Ghana (GGDP 1991). Higher adoption rates for improved seed reflect the greater availability of maize seed compared to fertilizer and the fact that improved varieties can perform better than local varieties under low-input conditions (i.e., without fertilizer).[3] Also, research on fertilizer use has emphasized a single recommendation for wide areas, which does not account for the diversity of smallholder situations and the acute cash constraints under which they operate. In addition, for many years agricultural researchers emphasized chemical fertilizer almost exclusively, at the expense of research on alternative means of maintaining soil fertility from internal sources of nutrients such as green manure, alley cropping, and animal manure. It is important to seek a balanced approach to improving soil fertility that combines both organic and inorganic sources of nutrients.

Research has also been conducted on a number of other management practices, which farmers have adopted on a limited scale. Small-scale farmers often reject recommendations for labor-intensive practices such as precise plant spacing, frequent weeding, and separate operations to apply fertilizer; consequently, the profitability of other elements of the recommended package is also affected. Experience from many countries has shown that seasonal labor availability is an important constraint on the acceptance of improved management practices such as plant spacing and weeding.[4] Even where land is in short supply, seasonal labor shortages often decisively influence farmers' choice of technology for several reasons: Hand-hoe agriculture demands a great deal of labor, off-farm work is important in many areas, and a pool of landless rural laborers is not available when demand for labor is greatest (Low 1988). It is therefore critical to evaluate new technologies in terms of their effect on the returns to labor.

Reflecting this labor constraint, farmers in the savanna of western Africa and much of southern Africa and Ethiopia have adopted animal traction in maize-based systems. A seasonal draft power constraint often emerges, however, because animals are in short supply or poor condition during the peak demands for land preparation (Collinson 1987). This situation has led to efforts to develop technologies to reduce tillage. Extensive work on reduced tillage in Zimbabwe has demonstrated the potential of this approach. It is still too early to assess success in terms of farmers' adoption, however, because farmers must also use chemical weed control (Shumba, Waddington, and Rukuni 1992) and retain crop residues, which have considerable economic value as forage—especially in drier areas (McIntire, Bourzat, and Pingali 1992).

There is little doubt that research on crop and resource management to overcome seasonal labor constraint and maximize returns to cash inputs while conserving the soil base and enhancing soil fertility over the longer run will go a long way toward increasing productivity and sustainability of maize-based systems (Lynam and Blackie 1994). Research on these constraints is increasing, but success, measured in terms of adoption, remains rare. Even when such technologies become available, special efforts will be required to transfer and adapt them to local farmers' situations, given that many crop and resource management strategies are fairly knowledge-intensive. In short, progress with crop and resource management research has been and will continue to be slow, because technologies will have to be adapted to specific situations and will be influenced by agroclimatic circumstances, population pressure, labor availability, and the stage of infrastructural and institutional development.

Returns on Investment in Maize Research

The adoption of improved maize has had a significant impact on maize production in Africa. The use of hybrids has increased farmers' maize yields by at least 40% in favorable areas. The evidence suggests that even in dry areas and drought years (such as 1991–1992), hybrids possess at least a 30% yield advantage over traditional varieties (Byerlee and Heisey 1993). The yield advantage of improved OPVs over local traditional varieties is 15 to 25% in tropical areas (Morris, Clancy, and López-Pereira 1992). Adoption of improved varieties and hybrids with these yield gains on over 40% of the area may account for over half of the annual growth in maize yields in Africa since 1970. In addition, the availability of early-maturing varieties and hybrids has enabled maize area to expand, especially in the drier savanna areas.

Several recent studies have evaluated the returns on investments in maize research in Africa (Table 9.3). Five of the seven studies concluded that the investment in maize research had provided high annual rates of return on investment, usually in excess of 40%. Not surprisingly, Kenya and Zimbabwe, whose success with maize research is well-known, feature among the countries showing high returns on investment (Karanja 1990; Kupfuma 1994). One of the highest returns, however, occurred in Mali, a relatively small-scale maize producer where low-cost adaptive research to screen varieties combined with good agronomic practices, input supply systems, and markets helped foster rapid growth in maize production (Boughton and de Frahan 1994).

Table 9.3 Sub-Saharan Africa: Summary of Estimates of Returns to Investment in Maize Research

Region and Country	Time Period	Rate of Return (%)	Source
Eastern Africa			
Kenya	1955–1988	40–60	Karanja (1990)
Uganda	1985–1996	< 0–15	Laker-Ojok (1994)
	1985–2006	27–58	
Southern Africa			
Malawi	1953–1992	4	Smale and Heisey (1994)
	1977–1992	63	
Zambia	1978–1991	100[a]	Howard (1994)
	1978–1991	< 0[b]	
Zimbabwe	1932–1990	44	Kupfuma (1994)
Western Africa			
Ghana	1968–1991	74	Sanders, Bezuneh, and Shroeder (1994)
Mali	1969–1991	135	Boughton and de Frahan (1994)
	1962–1991	54	

Notes: a. Includes only research and extension costs.
b. All costs, including additional marketing costs.

The studies that break down returns to research by time period, however, demonstrate the sensitivity of the results to the time period used (Oehmke and Crawford 1996). Thus Uganda, which has experienced low returns to maize research to date, is projected to experience high returns in the future, given current adoption trends. On the other hand, the high returns in Kenya and Zimbabwe are based on research that was conducted in the 1960s. Many farmers continue growing hybrids developed in the 1960s, because recent research has failed to deliver new streams of better-performing hybrids.

Potential for Future Productivity Gains Through Breeding Research: Strategic Issues

A strategic decision confronting all research programs for small-scale maize farmers is the relative emphasis to give to developing hybrids or OPVs. Recent evidence suggests that hybrids can perform as well as or better than local varieties and OPVs under low-input conditions (see Chapter 5). Nevertheless, many contend that hybrid maize is inappropriate for small-scale farmers, because hybrid seed must be purchased annually, requiring that farmers have cash at planting time and a reliable local supply of quality seed. Experience suggests that some countries in eastern and southern Africa have done a good job of providing hybrid seed at competitive prices *even to small-scale farmers,* although these countries generally have good infrastructure.[5]

On the other hand, OPVs have had less of an impact than expected, because low profit margins in producing OPV seed have discouraged private seed suppliers from investing in the industry. In most cases, seed of OPVs has been distributed to farmers through various donor-assisted projects, especially in Nigeria, Zaire, Mozambique, and Ghana. Most of these projects provided a one-time injection of new seed instead of developing a seed industry capable of regularly replenishing seed. Some countries are now experimenting with small private seed companies (often family owned), private nongovernmental organizations (NGOs), or farmers' cooperatives, combined with active support from the public sector to provide credit and training in seed production for OPVs (Cromwell 1996). It is too early to assess whether these experiments will result in viable small-scale seed industries for OPVs.

A second major issue related to future productivity gains is the extreme instability of maize yields in many maize-producing regions of Africa (Chapter 2). Unstable yields are largely the result of weather conditions, although disease and pest problems play a role as well. Given that maize production in some countries has shifted from large-scale to small-scale farms and to more marginal production environments, yield instability may be increasing. This raises the issue of whether breeders should place more emphasis on improving yield stability and less on increasing yield potential, especially since farmers' yields are so much lower than the genetic potential.

Considerable progress has already been achieved in stabilizing maize yields by breeding for resistance to disease and insect pests (especially maize streak virus). Work on drought tolerance also promises to alleviate (although not eliminate) the effects of the periodic severe droughts that affect even the relatively favorable maize-producing environments, especially in southern Africa (Edmeades, Bolaños, and Lafitte 1992).

Biotechnology has considerable potential to enhance the efficiency of conventional breeding programs and to enhance yield stability by incorporating genetic resistance to insects and specific herbicides in maize germ plasm and tolerance to the parasitic weed *Striga*, which is becoming a major problem in many maize production systems. The major issue for Africa is how to gain access to this technology through the private sector, the IARCs, or the development of local research capacity. Any successful strategy for benefiting from the emerging biotechnologies will probably involve all three sources, but only a very few countries, such as South Africa, have the resources to establish their own biotechnology laboratories. Such laboratories, working in collaboration with the IARCs and private companies, can become regional centers for adapting new biotechnologies. Even so, the promise of biotechnology is becoming a reality much more slowly than earlier forecasts suggested (McCalla 1994).

To summarize, conventional maize breeding should continue to provide high payoffs to farmers, particularly in terms of the development of more locally adapted materials with more stable yields. The good potential for continued progress in developing new varieties and hybrids suggests that investments in maize breeding should be sustained at current levels. At the same time, increased attention is needed for research on soil and water management, soil fertility, and weed control (Blackie 1994a). The potential long-term payoff to research on these constraints is undoubtedly high, but realizing that potential will require a long-term, well-focused multidisciplinary effort on specific crop and resource management problems.

Revitalizing Maize Research Capacity

It is a fact of life that the productivity increases that will occur 10 to 20 years from now will originate with today's research investments. It is also a fact of life that sustained and rapid technical progress will not occur without a strong local capacity for generating and promoting new technologies over the long term (Lynam and Blackie 1994). Much of the success of hybrid maize in Kenya and Zimbabwe can be attributed to the remarkable continuity of the maize breeding programs in these countries. Over a span of 56 years in Zimbabwe (1932–1988), four senior maize breeders led a low-cost research program on hybrid maize (Eicher 1990). In contrast, Malawi's Department of Agricultural Research has had four directors in the past 10 years (Rukuni 1996).

Problems with research continuity are just one symptom of the deepening financial crisis that has engulfed many public research systems in Africa over the past decade. Donors now support over 40% of the total research expenditures in Africa (not including research at the IARCs), and the proportion of research supported by donors is much higher in many individual countries (Pardey, Roseboom, and Beintema 1997). Most of this support, however, has been earmarked for specific projects, with the result that donor-supported activities at the periphery of the research system have burgeoned, often to the point of dominating core research activities (Spurling et al. 1992).

The funding crisis has been aggravated by a management crisis in many research systems, so that available resources have not been effectively used. Many research institutions have been unable to articulate research priorities, provide incentives for scientists, or develop appropriate external linkages with farmers, agribusiness, and political leaders (Eicher 1989). As a result, NARSs have often been marginalized from mainstream agricultural development.

A number of measures are being taken to revitalize NARSs in Africa, including the development of research strategies and priorities, greater autonomy for public research institutes outside of the civil service, "rationalization" of the number of research personnel and experiment stations (in many cases resulting in significant downsizing), and collaborative programs to conduct research on a regional basis and also to coordinate research closely with the IARCs. It is still too early to judge the success of these initiatives. A recent evaluation of programs in six countries suggests, however, that significant progress has been made in restructuring and reorienting NARSs, implying that policymakers are giving greater attention to agricultural research than in the recent past (SPAAR 1995). Both African governments and donors will need to make an extended commitment if they wish to build the kind of research establishment that can serve African smallholders into the next century.

Given the small size of most countries in Africa, the role of regional and international research is particularly important. Regional research programs established during the colonial period did not survive independence, although the IARCs—nearly all of which operate in Africa—have partially substituted for regional research institutes. By the 1980s, over three-quarters of the maize varieties released in Africa were based, at least in part, on germ plasm provided by the IARCs.

Because most countries lack sufficient maize area to justify a comprehensive maize research program, they can benefit from collaborating with neighboring countries, especially those with similar ecoregions, and by actively importing and screening available technologies from elsewhere. Fortunately, the role of regional research collaboration is being recognized, and several regional organizations with strong NARS participation are in operation.[6]

The acute scarcity of public funds for agricultural research has also elicited repeated calls for privatizing research and outsourcing research to universities and private research firms.[7] Because hybrid seed technology allows appropriation (through trade secrets) of the benefits of research on hybrid maize, the private sector has become a major global player in maize improvement research. It is estimated that the private sector accounts for about half of the maize R&D expenditures in Latin America and Asia. In Africa, private-sector involvement in maize research is still in its infancy, outside of South Africa and Zimbabwe. The global experience reveals that effective seed delivery systems for small-scale farmers have been developed through a combination of public-sector research and private-sector seed production and distribution (Byerlee and López-Pereira 1993). Once the seed market is well established, the applied research needed to develop new hybrids and varieties will gradually be provided by the private sector (Chapter 12).

The Evolving Role of Extension

Without doubt, maize farmers have been major beneficiaries of the expansion of national extension systems. Extension was a driving force behind the diffusion of improved maize technology in all of the country studies presented in this book. For example, during the 1960s and 1970s, tens of thousands of demonstrations were laid out in Kenyan farmers' fields to advertise the benefits of hybrid maize and associated management practices. This contact with extension was important in farmers' decisions to adopt hybrid maize technology (Moock 1981; Karanja 1990). Despite these successes, management problems arose as the number of extension staff increased and operating budgets for travel and farm visits decreased.[8] In addition, the messages and recommendations promoted by research and extension were often inappropriate for smallholders, especially resource-poor farmers lacking good access to markets.

General disenchantment with extension led to three major experiments in the 1980s and 1990s to strengthen both the management and the relevance of extension services: (1) the on-farm or farming systems approach to research and extension, (2) the Training and Visit (T&V) extension system, and (3) the Sasakawa-Global 2000 (SG 2000) extension demonstration approach.

On-Farm and Farming Systems Approaches

The farming systems approach to research and extension (FSR/E) was developed in the late 1970s to assist researchers and extension workers with developing technologies for African smallholders. The approach, which gained wide popularity in Africa in the 1980s, featured on-farm participatory surveys and experimental methods to involve farmers in technology development and diffusion. The FSR/E explicitly incorporated elements of smallholder farming systems that influence the acceptance of new technologies, such as intercropping, seasonal labor bottlenecks, draft power and cash constraints, and the management of family food security over the year (Collinson 1987). Another hallmark of FSR/E was the recognition that farmers, even within a given agroecological zone, differ considerably with respect to resource constraints, household objectives, and managerial capacity (Low 1994). Researchers sought to identify target groups of farmers ("recommendation domains") encompassing relatively homogeneous agroclimatic zones and socioeconomic circumstances for the purpose of developing more location-specific recommendations.

The 1980s saw a tremendous effort to build capacity in FSR/E within national research programs and universities. Much of the experience with FSR/E was based on work in maize-based farming systems (Collinson 1987). Training programs gave thousands of researchers and extension agents a valuable understanding of African smallholder farming systems and the need to develop strong linkages among commodity researchers (e.g., plant breeders), social scientists, extension workers, and farmers so technology could be better designed to fit the needs of target farmers.

The FSR/E approach did not meet early expectations that it would dramatically increase farmers' adoption of technology for major food crops (Heisey and Waddington 1993). The major constraints were on implementing the FSR/E approach, poor research-extension linkages, the lack of effective input delivery systems, and policy-induced price distortions. Where effective linkages were developed with extension, as in Ghana in the 1980s, adoption was impressive (Chapter 7). Finally, FSR/E put too much emphasis on developing technologies for the existing policy environment (e.g., lack of reliable input supply) at the expense of focused efforts to change that environment.

The Training and Visit System

The T&V extension system was implemented at the initiative of the World Bank to reform the *management* of extension systems, although in most cases adoption of the T&V approach implied some expansion in the number of extension workers. Described as "a hierarchical organized method of extension management designed to exclusively focus on technology and to deliver selected and timely messages to farmers with strict regularity" (World Bank 1994b), the T&V system trained village extension workers and provided the means for regular meetings with contact farmers. Contact farmers, in turn, were expected to relay specific crop production recommendations to farmers in their villages.

The T&V approach spread rapidly throughout Africa in the 1980s with the assistance of loans from the World Bank. To date, 27 countries in Africa have implemented the approach; in almost all cases, T&V projects have helped extension agencies to reach greater numbers of farmers (Cleaver 1993a). An evaluation of the T&V approach in Kenya and Burkina Faso concluded that it successfully encouraged the adoption of technology and enhanced farmers' productivity. In Kenya, farmers who had contact with extension workers obtained significant increases in maize yields, and the rate of return on the extension investment was found to be high (Bindlish and Evenson 1993). A more recent study concluded that the T&V approach had a favorable impact on farmers' adoption of new maize technologies in Kenya, especially small-scale farmers (Hassan, forthcoming).

Nonetheless, there has been considerable debate about the fiscal sustainability of the T&V approach after donor aid has been terminated. A World Bank evaluation found that at least half of the extension projects in Africa were rated "unsatisfactory" (World Bank 1994b). The study identified the following limitations with implementing the T&V approach.

- A rigid model was applied without sufficient attention to the variation in historical, cultural, economic, and institutional factors among and within countries
- Problems of financing recurrent costs threatened the long-term sustainability of extension reforms
- A top-down approach to delivering extension messages was reinforced, and messages were often based on standard packages of recommendations that ignored the heterogeneity among farmers
- Technologies appropriate to the circumstances of small-scale farmers were scarce, especially for resource-poor regions
- Linkages between research and extension were weak

A second generation of T&V extension projects in the late 1980s and the 1990s has sought to overcome these limitations by introducing greater flexibility to meet local needs. Obtaining sustained financing for extension programs remains a major challenge, however. As in Asia, where T&V was first introduced, many African countries have sought to develop more cost-effective and participatory approaches to extension. For example, in Malawi an extension manager recently reported that the T&V model was modified to suit local resource availability (Rukuni 1996). The World Bank, the major "donor" for extension, is currently reviewing its involvement in extension in Africa with a view to formulating a new strategy.

The SG 2000 Extension Approach

The extension program of SG 2000, an NGO, was launched in Ghana in 1986 to demonstrate that given access to available technology, small-scale farmers can dramatically increase yields of staple food crops. SG 2000 assists extension workers in the Ministry of Agriculture to conduct thousands of large (0.5 ha) demonstrations on farmers' fields to show the potential of a new technological package for raising crop yields (Borlaug and Dowswell 1995). SG 2000 also supplies credit on a revolving basis to ensure that components of the package, especially seed and fertilizer, are available to farmers. Recently, SG 2000 projects have broadened the range of interventions to include draft power and implements, on-farm grain storage, and agroprocessing technology. In 1996, SG 2000 projects were underway in 12 countries: Benin, Burkina Faso, Eritrea, Ethiopia, Ghana, Guinea, Mali, Mozambique, Nigeria, Tanzania, Togo, and Uganda.[9]

The decade-old SG 2000 project in Ghana has claimed the most success. The extensive coverage of on-farm demonstrations was undoubtedly a major factor in Ghanaian farmers' widespread adoption of maize seed-fertilizer technology (Chapter 7). The SG 2000 program has also experienced some success in extending maize technologies in Tanzania (Putterman 1995) and in convincing high-level African political leaders to promote smallholder agriculture more actively (Borlaug 1996). Although active dialogue with senior policymakers is a strength of the approach, SG 2000 has nonetheless found it difficult to mobilize ministries of agriculture to sustain the effort and ensure efficient input delivery after the demonstration phase is over (Eicher 1988; Tripp 1993; Farrington 1995; Putterman 1995; and Jiggins, Reijntjes, and Lightfoot 1996). Also, the dependence of earlier efforts on one or a few technological components was often inappropriate for meeting the diverse needs of African smallholders. Nonetheless, the SG 2000 country projects have demonstrated that there is considerable potential to increase maize yields and have served as a reminder that rapid adoption of new technologies is possible in Africa when relevant technology is combined with appropriate economic policies and markets.

Looking to the Future: Institutional Issues in Extension

The three extension initiatives discussed earlier have been valuable testing laboratories for improving the relevance of research and extension and increasing the rate of diffusion of new technology. Components of each model have been incorporated into most African extension services, but to date none of the models has been institutionalized within public extension services with financing by African governments. Rukuni (1996) recently reviewed the experience in institution building for research and extension in southern Africa and concluded that "prepackaged institutions" have not proven to be fiscally sustainable. He emphasized the importance of experimenting with pluralistic and demand-driven research and extension models for small-scale farmers rather than trying to import "successful models" from elsewhere.

The major issues now facing extension programs are how to sustain the gains that have been achieved in light of continuing budget shortfalls and how to introduce institutional reforms that make extension systems more cost-effective and demand driven. The widely lamented gap between research and extension is being addressed through the design of more integrated research and extension projects and more emphasis on farmer-led approaches to extension (Scarborough 1996). Farming systems diagnosis receives greater attention in T&V-based extension systems, and more attention is being given to reaching women, who are important but neglected clients of most extension systems.[10]

These approaches, however, although a step in the right direction, do not give rise to demand-driven systems. A major issue now is how to involve farmers in financing and governing pluralistic extension systems that involve collaboration among the traditional public-sector system, NGOs, and the private sector (e.g., seed and fertilizer dealers). For example, NGOs, which often have an advantage in articulating grassroots demands, are rapidly expanding their role in natural resource conservation. To this end, greater emphasis is being placed on strengthening local farmer organizations with the expectation that they will eventually be able to manage and finance at least some of the local costs of extension programs.

Conclusions

The evidence marshaled in this chapter reveals that investments in research and extension have generated some impressive achievements in maize production. Farmers are now growing improved varieties and hybrids on 40% of the maize area. Adoption of improved maize varieties in Africa compares favorably with Asia and Latin America, and rate of return studies show that public investment in maize research has produced high returns.

But Africa's maize success story has some important qualifiers. First, the use of improved maize varieties has been patchy, concentrated in fewer than 10 countries. Some large maize-producing areas have scarcely benefited from improved maize varieties. Identical maize production packages have yielded different results in neighboring countries owing to variations in farmer support services (often because of infrastructure) and pricing and input supply policies. A second qualifier to the maize success story is that farmers have not adopted the complementary improvements in cultural practices that would enable them to exploit the potential of improved maize seed. As a result, widespread use of improved maize varieties has not caused national maize yields to rise as expected. Third, building sustained institutional capacity to conduct effective research and extension for smallholders remains an elusive goal in most countries. National technology systems have been unable to garner reliable domestic political and financial support, and dependence on foreign aid to support these systems is increasing.

It is now clear that improved maize seed alone cannot provide the impetus needed for Africa's emerging maize revolution to fulfill its promise in smallholders' fields. Concerted efforts are needed to improve crop management. The organization of research on critical crop management problems, such as declining soil fertility, will require multidisciplinary collaboration over many years by research teams closely linked to extension, NGOs, policymakers, and input delivery agencies. It is important to be realistic, however, about the long time frame needed to achieve payoffs from this research, given the complexity of the task and the management intensity of the technologies that are likely to be required.

Extension programs have been central to transferring maize technologies to African farmers. Many extension programs have favored maize over other crops, but the dearth of appropriate technologies for smallholders has meant that the impact of extension has been less widespread or comprehensive than it might have been.

Weakened by crises in management and funding, research and extension systems have reached an important crossroads. Ways must be found to improve operating budgets, enhance efficiency, and integrate the efforts of a wider array of entities from the public sector, the private sector, NGOs, and—especially—farmers into both technology development and dissemination. In recent years, African governments and donors have been experimenting with new institutional models for research and extension. These experiments have made important contributions but have yet to be politically and financially sustainable. Nor is a single model adequate for the diversity of situations in Africa.

Notes

1. Pardey, Roseboom, and Beintema (1997) estimated that agricultural research expenditures in Africa increased in real terms by 6.6% annually in the 1960s and by 3.7% in the 1970s and declined by 0.3% in the 1980s.

2. Twenty-eight African countries are significant maize producers (that is, production surpasses 100,000 t of maize each year), and maize production in these

countries averages 700,000 t per country. (Rice production in Asia, however, averages 10 million t per country, even when India and China are excluded from the calculations.)

3. Results from hundreds of on-farm demonstrations in Malawi revealed that hybrid maize without fertilizer yielded significantly better than local varieties, even in a severe drought year (Byerlee and Heisey 1993).

4. Increased plant density and line planting have been adopted by farmers, as long as these practices do not conflict with seasonal labor demands and intercropping systems (e.g., GGDP 1991).

5. In Tanzania, where only 10 to 15% of rural roads are passable throughout the year, a large number of farmers who adopted hybrid seed through the SG 2000 extension program had to recycle their seed the next season because of the lack of a reliable supply of hybrid seed.

6. For example, a maize improvement network was recently established in southern Africa to promote collaboration and flows of maize germ plasm among NARSs in the region. Another network is being formed to foster cross-country collaboration in research on soil fertility.

7. The Agricultural Research Council in South Africa was advised to subcontract one-third of its national research budget to private firms and universities by the year 2000 (Corbett and Coulter 1995).

8. The number of agricultural extension workers in sub-Saharan Africa (excluding South Africa) increased almost threefold, from 21,000 in 1959 to 57,000 in 1980 (Judd, Boyce, and Evenson 1987:13).

9. Projects in the Sudan and Zambia have been phased out.

10. Hassan, Ngure, and Njoroge (1994) found significant discrimination against female farmers in extension programs in Kenya.