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Maize Technology and Productivity in Malawi

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More than any other people in the world, Malawians depend on maize as a staple food: Two-thirds of the food calories consumed daily in Malawi come from maize. Ninety percent of the cropped area is planted to maize, which is produced almost entirely by smallholders cultivating under 5 ha.

Increasing population pressure and declining farm size leave little doubt that the additional maize production required to feed Malawi's people in the future must be obtained almost entirely through higher maize yields. Since maize production has not kept pace with population growth, per capita consumption has declined steadily over the past two decades. The rural wage, denominated in terms of the maize price—a good indicator of rural poverty—has also fallen. Higher maize yields are therefore essential to reverse the downward trend in both income and consumption (Heisey and Smale 1995).

Until recently, most of the maize area was planted to local varieties, but Malawi's distinctive combination of physical and cultural endowments suggests that high-yielding maize varieties have great potential for increasing productivity. Semiflint hybrids released in the early 1990s have been well accepted by smallholders. These hybrids are attractive to both commercial and subsistence producers, because they satisfy the grain texture preferences of farmers who produce maize for their own consumption[1] and generally yield more than unimproved varieties, even under low-input, low-management conditions. Declining soil fertility and inadequate institutional support for seed research and input distribution, however, constrain the prospects for attaining the substantial yield increases Malawi will need to feed its people year after year.

To provide a basis for comparison with other maize-producing nations of Africa described in this book, this chapter will outline some of the factors affecting both the development of improved maize seed in Malawi and maize productivity through the early 1990s. The next section, an overview of key historical and cultural issues affecting maize productivity in

Malawi, explains critical features of the institutional structure for distributing improved seed and fertilizer through 1993, when the government and institutions changed. Diffusion patterns for seed and fertilizer, and evidence on the performance of recent research releases, are summarized in the second section of this chapter. Prospects for the future are discussed in the final section.

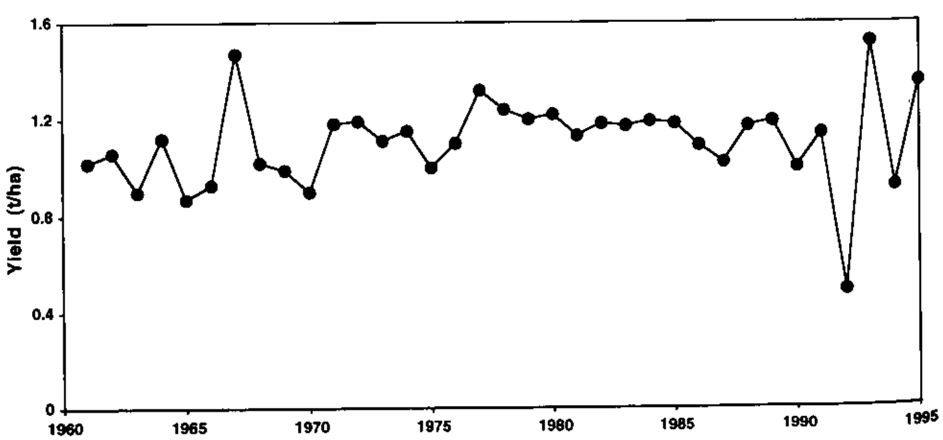
Historical, Cultural, and Institutional Factors

Land Use and Population

Most of Malawi is well suited to rain-fed maize cultivation. Historically, the relative fertility of the soil has contributed to migrations of African populations from surrounding regions. In the twentieth century, changes in cultivation intensity have accelerated the depletion of much of the country's natural fertility (Heisey and Smale 1995), and declining soil fertility is now a major constraint on maize production.

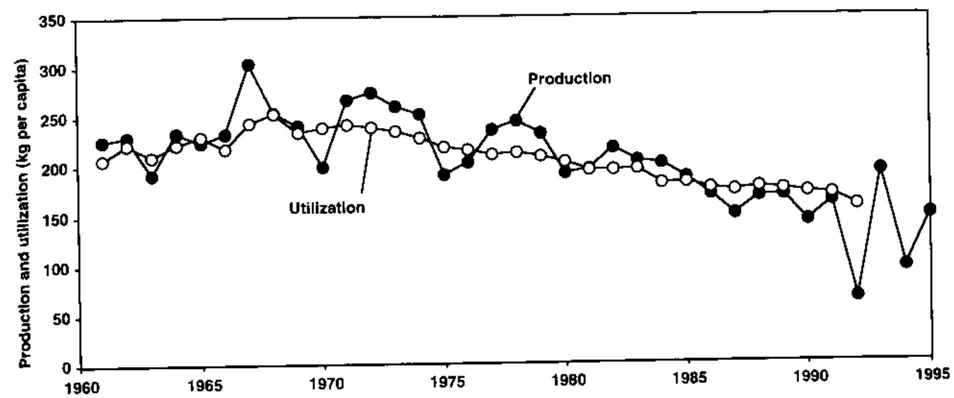
From 1961 through 1991, maize output increased by 1.8% per annum, or a total of 55%. Three-quarters of the estimated increase in total production resulted from an expansion in maize area. Yields overall appear to have increased at a small but statistically significant rate of 0.4% per annum (Figure 5.1). Per capita maize production declined over the past three decades, because production lagged behind the annual population growth rate of over 3.0% (Figure 5.2).

Figure 5.1 Malawi: Maize Yields, 1961–1995



Source: Calculated from FAO (various years).

Figure 5.2 Malawi: Maize Production and Utilization Per Capita, 1961–1995



Note: Utilization per capita after accounting for net trade and stock changes.
Source: Calculated from FAO (various years).

Malawi is often characterized as a "land-scarce" country. Although additional land has been planted to maize over the years, much of this new area, at least in the more densely populated Southern and Central Regions,[2] was probably shifted from other crops rather than taken out of long-term fallow[3] (Heisey and Smale 1995). In recent decades, the ratio of the agricultural population to cultivated land area has continued to increase, meaning that the size of farmers' holdings has declined and the distribution of holding sizes has been increasingly concentrated in the smaller size categories. In 1990, more than 90% of farm households cultivated less than 3 ha.

One major source of the downward pressure on the size of smallholders' farms is generally believed to be the diversion of land for producing export crops on estates.[4] Local land shortages occurred after 1900, partly because as much as 15% of the land in the Southern Region was occupied by European planters (Pachai 1973). During the 1950s, the colonial government acquired substantial amounts of European-held freehold land for redistribution to Africans. After independence in 1964, the government encouraged Africans to establish estates for producing export crops. The number of estates proliferated in the 1980s, although their average size diminished.

Along with rising population densities and the changing structure of land use, the sheer dominance of continuously cropped maize in the farming system contributes to declining soil fertility. The area planted by smallholders to maize and maize mixtures rose from 65 to 75% of cultivated area in the early 1960s to 75 to 85% of cultivated area 30 years later

(Heisey and Smale 1995). Survey data for three of the five major maize-producing Agricultural Development Divisions suggest that less than 10% of smallholder maize area is planted after fallow, the median length of fallow is only three years, and a mere 0.5% of the area planted to maize had been in long-term fallow.

The growing population and unfavorable transport situation, both aggravated by the war in Mozambique, have also contributed to the declining availability of maize per capita. From 1970 to 1990, per capita calorie consumption from maize fell by 0.7% annually (Figure 5.2). If increasing incomes had led to more diversified diets, decreasing consumption of maize might be considered a favorable development. The evidence does not support this interpretation, however. Over much of the 1980s, per capita income in Malawi actually declined (World Bank, various years). Rural wages, denominated in terms of the maize price, rose from the 1950s to the late 1960s, only to decline since then.

Since maize production has not kept pace with population growth, the staple food appears to have become more costly. As maize becomes more dominant in the cropping system, alternative crops that could improve smallholder incomes are relatively less likely to be planted. Maize yield increases may be necessary not only to reverse the decline in per capita consumption but also to stabilize income. As cropping patterns have become less diverse, the risk of poor nutrition in the population, which already experiences serious child malnutrition problems, has likely increased (Ferguson, Millard, and Khaila 1990).

The Cultural Significance of Maize in Malawi

For Malawi's smallholders, "maize is life" (*chimanga ndi moyo*). The ideal of producing sufficient maize for the household to use in the stiff porridge (*nsima*) that is the staple dish "informs everyone's actions and rationales for their actions before, during, and after the maize harvest."[5] Each "hungry season," when their maize stocks have been depleted, many farm households face undernutrition as maize prices rise prohibitively and supplies in local markets fluctuate. Dietary preferences and the risks associated with relying on official markets imply that a major objective of farm household decisionmaking is to produce enough maize to satisfy annual subsistence needs.

Maize is believed to have replaced sorghum and millet as the dominant staple in Malawi sometime after 1900. Although evidence is inconclusive, most of the dominant maize land races loosely referred to as "local maize" (*chimanga cha makolo*)[6] are probably descended from maize brought by the Portuguese to the eastern coast of Africa in the sixteenth century to supply garrisons and caravans (Miracle 1966). Literally, *chimanga cha makolo* means "maize of the ancestors."

Farmers have long emphasized flint grain texture in selecting their maize seed. Flint maize types have a higher proportion of hard starch granules in the kernel than dent maize types. When processed using traditional methods, flint maize has a higher flour-to-grain extraction ratio in the production of refined white flour, because the germ separates more easily from the bran when the grain is pounded in the mortar.

Traditionally, rural women produce the refined white flour (*ufa woyera*) they prefer for preparing *nsima* through a long process in which harvested maize is shelled by hand, dehulled by pounding it with a mortar and pestle, winnowed, fermented by soaking (which gives it a unique flavor), washed, dried in the sun, and pounded again once or twice. The introduction of low-cost hammer mills has been widespread, but rural women continue to produce flour by the taxing conventional method, most substituting the grinding mill for the mortar in the final (second or third) stage of pounding (Smale et al. 1991).[7] The family's annual maize harvest is typically stored in the husk, without chemical treatment, in a raised cylindrical structure called the *nkhokwe*. Farmers also state that the husk cover and harder grain of the dominant local maize varieties protect them longer from the weevils that compete for the family's stored grain supply (Ellis 1959; Sibale 1988).

The vast majority of farm households produce local flint maize for home consumption. The preference of farm households for consuming flint maize (like *chimanga cha makolo*) reflects their observation that the yield of improved dent maize is significantly reduced by on-farm processing and storage losses.

Despite their suitability for home food processing and their ability to withstand storage insects, local varieties have some important disadvantages. The plants are tall, take a long time to mature, and yield poorly even when chemical fertilizer is applied. Yields of local maize in farmers' fields (including fertilized and unfertilized maize) average about 1 t/ha. The typical family of five must plant more than 1 ha of these varieties to meet annual subsistence requirements. Today, more than two-thirds of all smallholders cultivate less than 1 ha of land (House and Zimalirana 1992).

The poor yields of local varieties compared to improved materials may result in part from the limited range of genetic content (compared to that found in a center of origin for a crop species) and possible deterioration in landraces over time. The "yield gap" between the maximum maize yields obtained on experiment stations and national average yields is about 9 t/ha (Edmeades 1990). Part of this gap reflects measurement and statistical error, but various estimates indicate that between 25% and 45% of the "true" gap can be attributed to genetic differences (Edmeades 1990; Kydd 1989). In the trials cited by Kydd (1989), hybrid maize yields were approximately 4 t/ha higher than local maize yields when both kinds of maize were grown under favorable management and fertility conditions.[8]

Maize Seed Research[9]

The colonial agricultural department began testing maize lines imported from the United States, South Africa, and Zimbabwe at the beginning of the twentieth century (Rusike 1995). In the 1940s, S. Hoyle began collecting maize landraces and inbreeding local materials to produce pure lines (Kydd 1989). After the Great Famine of 1949, the administration initiated research into higher-yielding food crops, including hybrid maize. Chitedze Agricultural Research Station was established, a chief agricultural research officer was appointed to coordinate national research, and R. T. Ellis was assigned to begin research on maize synthetics and hybrids. Ellis and other colonial administrators recognized the importance of grain texture to smallholders, and many of these first synthetics and hybrids were semiflint types (Ellis 1959; Rusike 1995).

Following independence, the post of plant breeder was filled intermittently by a series of expatriates and Malawians on short-term assignments (Ellis had resigned in 1959). Research focused on testing lines rather than new materials, and breeding lines deteriorated because of poor seed maintenance practices related to staff vacancies and insufficient supplies and funds. From 1967 to 1977, the hybrid maize breeding program was discontinued. During that period, the breeding program switched emphasis toward the development of improved open-pollinated varieties (OPVs) with flint grain texture for smallholders. To satisfy the limited demand of estate owners and larger smallholders for commercial maize seed, seed of high-yielding dent hybrids such as SR52 (the highest-yielding maize hybrid in the region at that time) was imported from Zimbabwe or South Africa.

By 1977, the hybrid maize breeding program had been officially restored, and several dent hybrids, as well as semiflint composites, were subsequently released. The three senior breeders, however, were sent for training overseas during the 1980s, and technicians maintained breeding lines. In the late 1980s, the World Bank and other donors exerted pressure on the maize research program to emphasize flint grain texture in the hybrid breeding program. The national maize research team initiated its flint hybrid breeding program in 1987. To obtain the semiflint hybrids MH17 and MH18, the team top-crossed Malawian single-cross hybrids with a flint variety obtained through the International Maize and Wheat Improvement Center in Mexico. By using a top-cross (a nonconventional hybrid) and building on its earlier work with dent hybrid lines and flint OPV materials, the team was able to release the new semiflint hybrids within the relatively short period of three years.

There are several ways in which the release of MH17 and MH18 represents a plant breeding success. First, after years of technical service, national scientists were eventually given training and awarded a leadership role. Second, the release of MH17 and MH18 represents a fruitful collaborative

effort between national scientists and scientists working for an international research institution. Third, the breeding effort demonstrates the positive effects on research of stable, although relatively modest, donor funding. Fourth, MH17 and MH18 represent a deliberate scientific effort to incorporate the concerns of small farmers into plant breeding strategies. The internal rate of return to maize research in Malawi is likely to be fairly high, even with an adoption ceiling of only 25% (Smale and Heisey 1994).

The Institutional Structure for Distributing Improved Seed and Fertilizer

In the past, hybrid maize seed has been diffused in fixed proportions with a recommended level of fertilizer as a technical package; the package came in one size suitable for production on one acre (0.4 ha). The package was distributed through credit clubs or formal associations of farmers, and credit was typically recovered when maize was delivered to the nearest outlet of the Agricultural Development and Marketing Corporation (ADMARC).[10] This system was effective in delivering a technology to a minority of relatively advantaged smallholders and for drawing maize surpluses into the official marketing and storage system for later redistribution to food-deficit households.

Credit clubs were generally fairly small. Club members shared common socioeconomic characteristics: They were among the most advantaged of villagers. Default by any group member resulted in loss of eligibility, so the group's continued access to credit depended upon the compliance of each member. Club members were bound by stringent repayment procedures and the threat of punitive measures to return the loan in-kind at the end of the season. In recent years, an estimated 65 to 70% of all fertilizer and 70 to 80% of all hybrid seed used by smallholders was supplied to them annually through these clubs (HIID/EPD 1994). Extension advice on how to use hybrid seed and fertilizer was also largely restricted to members of credit clubs;[11] this advice emphasized a uniform set of recommendations for seeding rate, pure stand cultivation, and fertilizer application.

In 1993, following several years of erratic rainfall and in the midst of political turmoil over the vote for multiparty elections, the smallholder credit system was plagued by widespread defaulting for the first time in its history. The credit system collapsed, and sales of seed and fertilizer contracted severely. The effect of the disrupted credit program on seed and fertilizer sales continues to be evident. The collapse of the credit system, however, was more a result of important recent political changes within Malawi than of problems inherent in the credit system's design.

There are also technical problems associated with delivering seed and fertilizer as a package. Until recently, neither the composition of the package nor its size could be varied to suit the different objectives and needs of smallholders. Fertilizer costs are high[12] and constituted the major portion of the cost of adopting the seed-fertilizer package. Yet, results from farmer-managed demonstrations have shown that the maize hybrids currently grown in Malawi yield more than local varieties, even with low to zero levels of nitrogen. Partial budget analysis also suggests that for many farmers, the economically optimal level of fertilizer may be far below the level that has been promoted through the package; for others, the adoption of hybrid seed alone may be economically optimal (see the next section). In other words, more widespread adoption of seed could occur with a more flexible combination of technologies. Adoption of seed alone could improve the social welfare of smallholders, even though it might not generate the dramatic yield differences that occur when hybrid seed is adopted with high levels of management and fertilizer.

No easy solution exists to the input distribution problem in Malawi. The diffusion of hybrid maize seed has been constrained not only by offering seed, fertilizer, and extension advice through a credit package but also by certain features of seed supply and marketing. Production of seed relative to demand appears to have been limited over the years (Cromwell and Zambezi 1993). Until 1978, when the National Seed Company of Malawi was formed, ADMARC and the Ministry of Agriculture were responsible for producing seed. The National Seed Company was initially majority owned by ADMARC and minority owned by the Commonwealth Development Corporation, an institution of the British government. The transfer of seed production and other functions to the National Seed Company resulted in a number of related institutional improvements. In its initial years of operation (through 1980), however, the National Seed Company's sales of hybrid maize seed were sufficient to plant less than 5% of the smallholder maize area (Heisey and Smale 1995; Cromwell and Zambezi 1993). Since 1990, Cargill, a large, privately held multinational company, has been the majority owner of the National Seed Company; ADMARC and the Commonwealth Development Corporation retain minority shares.

Turning over seed multiplication to a private company has not solved seed supply problems. The National Seed Company's production costs appear to exceed ADMARC's sale price to farmers (Cromwell and Zambezi 1993). The company's largest client has been ADMARC, which absorbs the cost-price differential through a general government subvention. A competitor, Lever Brothers, began selling directly to farmers in 1992 and is now also permitted by law to sell seed to ADMARC. The National Seed Company also has begun to market seed directly to farmers in rural areas, although charging prices that are competitive with the ADMARC price may cause short-term losses because of cost-price differentials. As long as ADMARC remains the major client for the seed companies, seed sales will

depend upon how well ADMARC functions. Detaching seed sales from the ADMARC-smallholder credit system assumes that the physical and legal infrastructure for private marketing of seed is already in place. Although private traders now purchase grain from farmers and sell it to ADMARC in some areas, there is little evidence as yet of significant seed sales in rural areas by private traders.

Privatization is also too simplistic a solution for fertilizer distribution in Malawi. Large economies of scale in fertilizer production mean that Malawi, like most nations in Africa, will remain an importer and a price taker in a world market with considerable price variability. The high costs of transporting a bulky commodity from the African coast to landlocked Malawi and then to a large population of smallholders who farm less than 1 ha imply that distributors will require substantial capital and flexible financial arrangements. Institutional mechanisms other than the private market may be necessary to ensure fertilizer delivery to farmers. In a recent study of fertilizer policy in Malawi, the Harvard Institute for International Development (HIID/EPD 1994) concluded that although the marketing of fertilizers at subsidized prices through ADMARC makes private-sector marketing unattractive, fundamental problems with access to domestic capital and foreign exchange will continue to inhibit private-sector participation, even if price subsidies are removed.

Price and Policy Environment

Historical factors contributed to the slow formation of policies and institutions designed to support maize research and development. Before independence, most incentives for smallholder production were directed to the promotion of export crops, the most successful of which was tobacco. Maize was a subsistence crop produced or exchanged by Africans to feed themselves. The need to invest in maize improvement did not assume importance for policymakers until the Great Famine of 1949.

Since independence, estate owners have generally grown maize as a secondary crop in rotation with tobacco. Maize produced on estates is used to feed laborers or is sold after harvest to official markets, to be stored by the official marketing agency or industrially processed. Estate owners therefore have had little interest in promoting the breeding of a maize variety that satisfies the grain texture preferences (related to processing and storage qualities) of smallholders, who consume the maize they produce.

Over most of this period, the effects on smallholders of input and output pricing policies for maize could be generally considered secondary compared to policies regarding the pricing and licensing of export crops. Several features of the maize policy environment merit special note. Although African traders have been exempted from restrictions on trading produce since 1957, Asian traders were subject to restrictions from the

1970s, and ADMARC increasingly dominated agricultural marketing and enjoyed monopsonist/monopolist status for outputs and inputs. The consumer, purchase, and input prices of ADMARC have generally been pan-territorial and pan-seasonal, which effectively subsidizes producers and consumers in more remote areas.

In theory, ADMARC's maize producer price was to be set in the wide band between export and import parity. In practice, the producer price loosely followed the export parity standard, primarily because ADMARC had to export at a loss in years when relatively high prices helped to draw out a maize surplus. Input pricing was marked by a subsidy of about 25% on nitrogen fertilizer, although debate spurred by aid donors over phasing out the subsidy began in the 1980s. The most important policy factor affecting seed-fertilizer technology in this period was the decision to move to urea as a lower-cost source of nitrogen (primarily owing to lower transport costs).

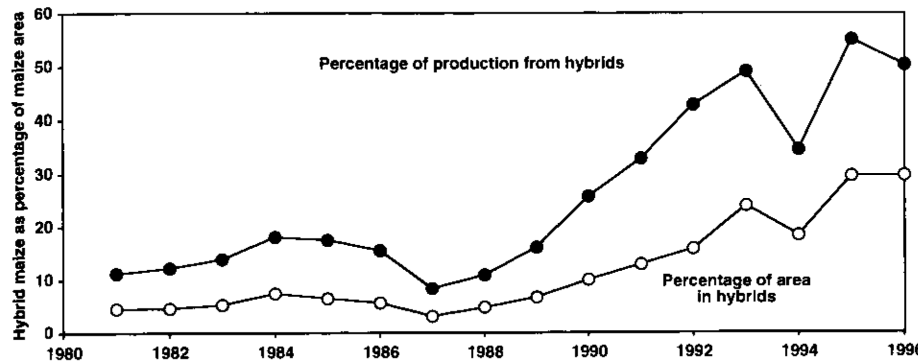
Diffusion of Improved Maize Technology

An estimated 0.3% of aggregate maize area in Malawi was planted to hybrids in 1970–1971.[13] By 1980, no more than 7% of the maize area was planted to composites (probably first-year seed) in any of the major maize-producing Agricultural Development Divisions. The limited anecdotal and survey evidence suggests that farmers did not perceive large yield advantages with many of the improved OPVs; only small amounts of improved OPV seed were available for diffusion; and other problems, such as lodging, were associated with some of the taller improved OPVs.

The diffusion of improved maize seed was sluggish in the mid-1980s. The lowest adoption rates occurred during the 1986–1987 season, the year following a financial crisis that prevented ADMARC from purchasing the hybrid maize farmers offered for sale. Two years after their release in 1990, the semiflint hybrids MH17 and MH18[14] covered an area that surpassed the total area planted to maize hybrids during the mid-1980s (Heisey and Smale 1995). Another downward fluctuation occurred in 1993–1994, when the credit system collapsed. In recent years, however, hybrid maize has accounted for about half of the total maize output (Figure 5.3), which underscores its importance in national food security.

Because MH17 and MH18 are both high yielding and have semiflint grain texture, they are attractive to farmers for either home consumption or sale, and they suit the objectives of a wider range of smallholders. In a 1991–1992 survey in which 150 farmers compared the performance of dent and semiflint hybrids with local maize in their own fields, mortars, and granaries, MH17 and MH18 ranked as well as the previously released dent hybrids in terms of yield and nearly as well as local maize in terms of processing and storing characteristics (Table 5.1).

Figure 5.3 Malawi: Diffusion of Hybrid Maize, 1981–1996



Sources: GOM/NSO (1984) and Ministry of Agriculture (1984–1996).

Table 5.1 Malawi: Farmers' Ranking of Yield, Processing, and Storage Characteristics in Maize Hybrids and Local Maize, 1991–1992 (percentage)

Ranking	Semiflint Hybrid MH18	Dent Hybrid MH12	Fertilized Local	Unfertilized Local	All Local Maize
Yield					
First	62	44	0	7	—
Second	27	44	31	14	—
Third	11	12	69	58	—
Fourth	0	0	0	21	—
Flour-to-grain extraction					
First	83	8	—	—	92
Second	17	4	—	—	8
Third	0	88	—	—	0
Insect resistance in storage					
First	82	17	—	—	100
Second	18	66	—	—	0
Third	0	17	—	—	0

Source: CIMMYT/Ministry of Agriculture Farmer Evaluation Survey, 1991–1992.

In the same survey, farmers reported obtaining higher yields from hybrids (both semiflint and dent) than from local maize in their own fields, under their own management conditions and input choice, in a drought year (Table 5.1; Smale et al. 1993). Objective evidence of the yield advantages of Malawi's hybrids is provided by four years (1989–1990 to 1992–1993) of farmer-managed, researcher-supervised demonstrations in the Central Region. During the drought year, as well as in other years, unfertilized hybrid maize yielded more than unfertilized local maize (Table 5.2). Coupled with the greater fertilizer responsiveness of hybrid maize, this finding suggests that at *any* level of fertilizer application, the expected yield of hybrid maize is greater than that of local maize (Jones and Heisey 1994). The results of other trials, whether conducted on farmers' fields or on experiment stations, appear to confirm this conclusion (Heisey and Smale 1995). The yield advantage of unfertilized hybrid maize over unfertilized local maize is likely to hold for at least three of the five ecological zones in Malawi (70% of the maize area).

The data also show that for any year and for any treatment for which spatial yield distributions could be compared, whenever hybrid maize and local maize yields are compared for equal levels of fertilizer, the cumulative probability of obtaining a yield lower than a given level is less for hybrids than for local maize. The stability of results over the years leads us to conjecture (with caution) that for many farmers in the main maize growing areas, the yield risk with Malawi's maize hybrids is less than with unimproved local varieties at any fertilizer level, including zero.

Results of partial budgeting analysis (Jones and Heisey 1994) further suggest that with subsidized prices, in all normal years hybrid maize at the recommended fertilizer levels is the economically optimal choice for all types of farmers. With unsubsidized prices, hybrid maize is always more profitable than local maize for maize-deficit households, although recommended fertilizer levels are not always economically optimal. For maize-surplus households facing unsubsidized prices, no particular technology alternative appears economically optimal in all seasons. Even when the

Table 5.2 **Malawi: Mean Yields (t/ha) of Maize Hybrids and Local Maize, With and Without Fertilizer, in "Normal" and Drought Seasons, 1989–1993**

	Unimproved Local Maize			Hybrid Maize		
"Normal" Season Fertilizer rates (N-P)	1989–1990	1990–1991	1992–1993	1989–1990	1990–1991	1992–1993
0-0	1.0	1.1	1.1	1.6	1.6	1.6
40-10	1.8	1.8	1.8	n.a.	n.a.	2.5
95-37	n.a.	n.a.	n.a.	3.8	4.0	3.8
Drought Season Fertilizer rates (N-P)	Unimproved Local Maize, 1991–1992			Hybrid Maize, 1991–1992		
0-0	0.4			0.8		
40-10	0.9			n.a.		
95-37	n.a.			1.9		

Source: Ministry of Agriculture/United Nations Development Program/Food and Agriculture Organization of the United Nations, Fertilizer Demonstration Program. Data were used from 21 sites in 1989–1990, 89 in 1990–1991, 101 in 1991–1992, and 136 in 1992–1993.

Note: n.a = data not available.

assumption of a high degree of risk aversion was imposed using a more general theoretical approach, in nearly all cases the economically superior treatments did not change from the risk-neutral case outlined here (Heisey 1994).

Several conclusions follow from these results. First, maize-deficit households, which may be less likely to have experience with seed-fertilizer technology, have greater economic incentives to adopt the technology than maize-surplus households. Second, in cases where hybrid and local maize can be compared at the same level of fertilization (no fertilizer or 40–10 N-P_2O_5 in 1992–1993), hybrid maize is more profitable under nearly all circumstances. Even in cases where it is not, using hybrid maize covers the cost of the seed. When local maize and hybrid maize are consumption substitutes (Smale et al. 1993), it no longer makes economic sense to fertilize local maize. The large aggregate increases in fertilizer use on local maize in the late 1980s were associated with the use of dent hybrids, which were not consumption substitutes with local maize. Third, the principal effect of subsidies is on the use of fertilizer rather than of seed. Subsidies also appear to have the effect of encouraging maize-surplus households to use fertilizer at the recommended levels rather than encouraging adoption by maize-deficit households, which may not use fertilizer for the reasons summarized earlier.

Under most assumptions, therefore, the yield advantages from using hybrid seed and fertilizer translate into economic advantages. Input-output price ratios and the type of growing season appear to be more decisive factors than farmer aversion to risk in determining which technology choices are economically optimal.[15]

The central finding that represents the most radical departure from the general preconceptions found in the literature about the use of high-yielding varieties is that even with low to zero levels of nitrogen and under modest management levels, and often in a year of moisture stress, the maize hybrids currently grown in Malawi yield more and in most cases are more profitable than the local maize currently grown. These advantages are associated with high-yielding varieties that are often thought, incorrectly, to "require" fertilizer.[16]

Seed and fertilizer are a divisible technology, meaning a farmer can use very small amounts of them (a handful of seed, a cup of fertilizer) and the cost per unit of land does not change with the extent of area planted. This means no economies of scale are associated with the technology itself, and it is neutral with respect to farm size. What introduces economies of scale into the adoption of seed-fertilizer technology in Malawi (what makes the technology more likely to be adopted by large-scale rather than small-scale farmers) are its packaging and its association with extension advice and the credit system. This distortion is reflected over time in the skewness of the adoption pattern by farm size (Table 5.3). In recent years, there is some evidence that through cash purchases, adoption of hybrid maize seed and/or fertilizer has increased, even in the smallest farm-size categories and among farm households headed by women (Smale et al. 1991; Peters and Herrera 1989). A significant amount of fertilizer (up to 45%) was also purchased with cash in the past (see Williams and Allgood 1990), before the closing of ADMARC's more remote market outlets and the expansion of the credit system in the early 1990s.

Both aggregate data and farmers' reports suggest that smallholders have tended to adopt fertilizer on local maize before adopting improved maize seed (see Heisey and Smale 1995; Table 5.3). This pattern may reflect the strong influence of smallholders' grain texture preferences on seed adoption before the release of the semiflint hybrids or the limited availability of improved seed, relative to fertilizer, in previous decades. Farmers' perceptions of declining soil fertility may also explain the pattern. Farmers who have little experience growing improved maize may not perceive differences in the yield response of improved and local maize grown with low levels of fertilizer.

Differences in cultural practices for maize in Malawi appear to be associated with variety, fertilizer use, or both. When small-scale farmers intensify their maize production through the use of high-yielding hybrid seed or inorganic fertilizer, they tend to increase their management levels through timelier planting and weeding, higher plant densities, or planting after a rotation crop.

Table 5.3 Malawi: Adoption of Maize Technology by Farm Size, 1985 and 1990

	Farm Size (ha)					
	<0.5	0.5–1.0	1.1–1.5	1.6–2.0	2.1–3.0	>3.0
Percentage of households headed by women						
1985	42	34	24	18	10	8
1990	51	29	19	9	15	9
Percentage of maize area planted to improved seed						
1985	2	2	6	8	15	25
1990	4	10	19	20	27	26
Percentage of farmers using inorganic fertilizer						
1985	9	16	25	40	44	54
1990	33	48	70	72	86	76
Average dose of fertilizer applied to hybrid maize (kg nutrients/ha)						
1990	46	64	62	81	83	61

Sources: Data for 1985 taken from Kydd (1989) and Sahn and Arulpragasam (1991). Data for 1990 were calculated from CIMMYT/ Ministry of Agriculture survey data, 1990–1991.

Implications for the Future

The one essential ingredient for improved maize productivity in Malawi is a real and renewed political commitment to the development of smallholder agriculture. Over the past few decades, the development strategy has favored estates at the expense of smallholders. In 1993, Malawians voted—for the first time in their history—in favor of a multiparty political system, and major institutional and economic changes have followed this decision. These recent political changes mark an appropriate juncture for rigorously analyzing the implications of policies on smallholder productivity.

Institutional

Several institutional changes are required to support technical innovations in Malawi over time. Perhaps the most urgent need is a national commitment to maize research. The maize program has been beset since its inception with both low absolute levels and unreliability of public funding. This problem expressed itself in staffing discontinuities that resulted in scientific stagnation, the loss of momentum in research, and the loss of breeding material. At a bare minimum, continuity in staffing and funding is necessary to maintain existing breeding material. Maintaining a flow of improved materials, or attaining better solutions for crucial crop management problems such as declining soil fertility, cannot be accomplished without this continuity. Lack of national commitment, in turn, exposes the maize research system to the whims of donor financing and donor-driven priorities.

The evolution of complementary roles for seed production and distribution systems is also critical to assure that technology reaches farmers. The very marketing arrangements that increased the National Seed Company's short-term profits (such as sales to smallholders indirectly through ADMARC and the credit club system) also increased its vulnerability to policy changes. Private seed companies need to develop their own markets, and a more decentralized structure may be needed to successfully distribute seed among Malawi's many smallholders. Furthermore, without long years of publicly funded maize research, neither the National Seed Company nor Cargill would have had maize hybrids suitable for dissemination. Interaction and cooperation between public and private institutions continue to be important in ensuring that existing hybrids are maintained and new ones developed. In the future, the pricing and structural implications of multinational dominance of the national seed system will need to be analyzed.

Technical

The yield advantages from using hybrid seed and fertilizer in Malawi have been confirmed by farm surveys and aggregate data. Each year from 1981 through 1995, the reported aggregate hybrid maize yield ranged from 2.4 to over 4 times the yield of unfertilized local maize. If the use of seed-fertilizer technology has increased, as we have documented here, then why have average maize yields not increased?

First, from 1981 through 1991, yields of unfertilized local maize fell by 2.0% annually; yields of hybrid maize fell by 1.1% annually. This pattern suggests that the increasing use of improved seed and fertilizer has only served to counteract underlying factors that negatively affect yield, such as declining soil fertility. Weather variability in recent years has also dampened the effects expected from greater use of a higher-yielding technology.

What will it take to sustain technical change in Malawi's maize production? Given the role of maize as a wage good and food staple in the economy, one simple but useful definition for sustained technical change is a rate of increase in maize output that matches population growth. Even under fairly optimistic assumptions for adoption ceilings and yield increases, projections suggest that to maintain the desired level of maize calories consumed by Malawi's growing population, further technological advances in maize production, as well as imports, are likely to become necessary.

Improved seed is not enough. Declining soil fertility and low management levels among smallholders need to be addressed in the longer term. A better understanding is needed of the dynamics of soil organic matter and the importance of other nutrients. With continuing deterioration in soil fertility and the high cost of imported fertilizer, solving the soil fertility problem may now be the highest maize research priority.

Notes

1. Most farmers produce maize for both home consumption and sale.

2. These are two of the three administrative regions of the country.

3. Fallow lasting more than 20 years.

4. The agricultural sector consists of the estate and smallholder sectors. Smallholders retain their land-use rights under customary tenure, which implies that land is held collectively and use rights are allocated through traditional authorities. Estates are defined legally in terms of their leasehold or freehold tenure status rather than farm size. Maize produced by estates accounts for less than 5% of total maize area, or 10% of total production (Mkandawire, Jaffee, and Bertoli 1990).

5. From villagers' statements reported in Peters and Herrera (1989:47–48).

6. "Local" maize refers to maize that has not been scientifically bred, although some maize farmers call "local" is produced from the seed of varieties released by the national research system. In general, in Malawi "local" refers to unimproved, open-pollinated maize varieties for which the seed is retained and managed by farmers.

7. Alternatively, either dent or flint maize can be processed on the farm as a coarser, less prestigious, whole-grain flour called *mgaiwa*. When women pound grain into *mgaiwa*, there is no difference in the flour-to-grain extraction rate for dent and flint maize. The relative nutritional strengths of *mgaiwa* and *ufa woyera* have been debated since the colonial period (see Kydd 1989). Women report that with some dent maize types, simple modifications in pounding methods may reduce processing losses (Smale et al. 1991).

8. Three other facts of maize physiology may or may not contribute to recent varietal deterioration among Malawi's landraces. First, unlike self-pollinating crops, maize has a high propensity to cross-pollinate. Traits expressed by one genotype may be difficult to maintain because of the high risk of contamination with pollen of other genotypes. Second, the dominance of maize in local farming systems means it is difficult to isolate fields to reduce outcrossing. Third, survey data suggest that a substantial proportion of the seed planted as "local maize" was actually obtained from other farmers in labor exchange or from the maize food grain market (Smale et al. 1991). Since most maize grain sold at official market outlets is now hybrid maize, "local maize" includes second-generation hybrid seed.

9. For details and supporting evidence, see Kydd (1989) and Smale and Heisey (1994).

10 . A parastatal marketing board, ADMARC delivers inputs; collects, transports, and stores smallholder crops; and sells maize grain to rural consumers.

11. An estimated 40% of extension agents' time was used in credit-related activities, according to the HIID/EPD study.

12. Fertilizer costs are high despite subsidies and the gradual shift from low- to high-analysis fertilizer.

13. Calculated from seed sales data reported by Quinten and Sterkenburg (1975) and FAO area figures (FAO, various years).

14. Except for some early work on semiflint hybrids under the colonial administration, all of the maize hybrids released by the national maize program from independence until 1990 were dent hybrids. Nearly all regional research with maize hybrids (Kenya, Zambia, Zimbabwe, and South Africa) has also produced dent hybrids.

15. It is important to remember, however, that "partial" budget analysis, as opposed to "whole-farm" analysis, assumes that one technique is substituted for another on all of a farmer's maize area. In fact, farmers in Malawi generally prefer to use a combination of seed types and fertilizer levels and have multiple reasons for doing so (Smale, Just, and Leathers 1994).

16. This conventional wisdom of the nonscientific literature is not borne out by research, which shows that improved maize with high yield potential yields more than maize with low yield potential across normal maize environments, with or without fertilizer.