

as were 31 private seed companies (including all of the industry leaders). Between them, these organizations controlled 97% of the total maize seed market in 1996. The survey could not be administered in a few countries due to civil strife, but given that these countries account for a negligible proportion of total regional maize area and production, the omissions are of minimal significance.

Data collection proceeded in stages. First, copies of the questionnaire were mailed to directors of national maize research programs and to senior researchers (mainly plant breeders) in public seed agencies and private seed companies. After the respondents had been given time to review the questionnaire and assemble information, they were personally interviewed, in most cases by one or more of the study authors, and in a few cases by experienced non-CIMMYT researchers. Following the interviews, data recorded in the questionnaires were extensively cross-checked for accuracy and consistency. During this process, staff of the CIMMYT Maize Program helped to resolve numerous questions related to the genetic backgrounds of commercial varieties. In a number of cases, the original respondents were contacted a second time to clear up inconsistencies.

The Maize Economy of Eastern and Southern Africa

Maize dominates the food economy of eastern and southern Africa, where it is by far the dominant staple crop grown by the vast majority of rural households.

Maize Production Environments

Maize in sub-Saharan Africa is produced in a wide range of production environments. Based on agro-climatic factors and grain maturity characteristics, the CIMMYT Maize Program has

identified eight distinct maize production environments, known as *mega-environments*:

- Tropical lowlands
- Tropical mid-altitude zones
- Tropical highlands
- Subtropical lowlands
- Subtropical mid-altitude zones
- Subtropical highlands
- Subtropical winter zones
- Temperate/subtropical zones

These eight mega-environments can be grouped into four basic agro-ecological zones:

1. **Lowland tropical zones** (0-1,000 masl) located in Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Somalia, South Africa, and Zambia cover about 18% of the maize area in eastern and southern Africa. Some areas feature a distinct rainy season, while in other areas rainfall is bimodally distributed. Maize is usually grown as a monocrop or intercropped with grain legumes, sesame, cassava, cowpea, pigeon peas, tomatoes, or rice.
2. **Wet subtropical zones** (900-1,500 masl, >1,000 mm annual rainfall) located in Angola, Burundi, Kenya, Malawi, Mozambique, Rwanda, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe constitute 49% of the area planted to maize in the region. Rainfall generally decreases as altitude increases. Some areas are characterized by bimodally distributed rainfall, which enables two maize crops to be grown each year. Soils range from deep fertile soils along river bottoms and in lake basins to well drained and easily worked upland soils.
3. **Dry subtropical zones** (900 –1,500 masl, < 1,000 mm annual rainfall) located in Ethiopia, Kenya, Tanzania, Uganda, and Zimbabwe constitute 16% of the area under maize in eastern and southern Africa. These zones are characterized by unreliable and inadequate rainfall, which discourages farmers from investing in inputs such as improved seed and chemical fertilizer.

4. **Highland zones** (>1,800 masl) located in Burundi, Ethiopia, Kenya, Lesotho, Rwanda, South Africa, Tanzania, and Uganda cover about 16% of the total area planted to maize in eastern and southern Africa. Highland zones are endowed with adequate to excessive rainfall, cool temperatures, and long growing seasons. The soils are highly fertile, well drained, and have high organic matter content.

Maize Production and Consumption Trends

Maize production statistics for sub-Saharan Africa show pronounced variability through time, reflecting the vulnerability of Africa's mostly rainfed maize production systems to extremely unpredictable weather patterns (Table 2). Disregarding short-term variability, over the longer term the area planted to maize has been expanding in eastern and southern Africa, growing at an annual average rate of 1.8% from 1961-70 before accelerating to 2.5% during the 1991-97 period. In contrast, no clear long-term pattern has been discernible in western and central Africa; during the past four decades, the area planted to maize in this region alternately expanded and contracted.

Maize yield growth has been similarly variable (Table 2). Throughout sub-Saharan Africa, annual growth in maize yields fluctuated around 1% during the 1960s and 1970s before accelerating noticeably during the 1980s and 1990s. In eastern and southern Africa, particularly large yield increases were realized during the mid- and late 1990s as maize

production recovered from the devastating drought that affected southern Africa in 1991/92. During the latter part of the 1990s, El Niño-related weather phenomena again disrupted maize production in a number of countries, especially in southern Africa, but on the whole the effects were less devastating than expected.

Maize production trends reflect combined effects of area and yield variability (Table 2). In eastern and southern Africa, periods of unfavorable weather have often been followed by periods of favorable weather, which has served to reduce the variability in production growth over the longer term. For eastern and southern Africa as a whole, maize production growth averaged about 2.2% throughout most of the 1960s, 1970s, and 1980s before accelerating sharply during the 1990s. Production growth has been much more variable in western and central Africa and actually fell to negative levels during the 1970s as a result of the Sahelian drought.

Consumption of maize is high throughout most of the region, reflecting its role as the primary food staple (Table 3). Maize accounts for over 50% of total calories consumed in eastern Africa and 30% of total calories consumed in southern Africa. In southern Africa, per capita annual consumption of maize averages more than 100 kg in several countries, including Lesotho (149 kg), Malawi (181 kg), South Africa (195 kg), Swaziland (138 kg), Zambia (168 kg), and Zimbabwe (153 kg) (CIMMYT 1999). In eastern Africa, per capita annual consumption is somewhat lower, ranging from a low of 40 kg in Burundi to a high of 105 kg in Kenya.

Table 2. Trends in maize area planted, yield, and production, 1961-97 (% annual growth)

	1961-70			1971-80			1981-90			1991-97		
	Eastern and southern Africa	Western and central Africa	All developing countries	Eastern and southern Africa	Western and central Africa	All developing countries	Eastern and southern Africa	Western and central Africa	All developing countries	Eastern and southern Africa	Western and central Africa	All developing countries
Area	1.8	0.9	2.0	0.4	-0.8	0.8	1.6	10.2	1.5	2.5	-0.9	1.4
Yield	0.7	1.9	2.8	1.9	0.4	3.0	0.5	3.3	1.6	3.6	2.5	1.9
Production	2.4	2.8	4.8	2.3	-0.4	3.8	2.1	13.4	3.1	6.1	1.7	3.3

Source: FAOSTAT online database.

Table 3. Maize imports, consumption, and utilization, 1994-96

	Eastern and southern Africa	Western and central Africa	All developing countries	World
Net imports (000 t), 1994-96	-588	119	27,937	-
Per capita net imports (kg/yr), 1994-96	-2	<1	6	-
Per capita consumption (kg/yr), 1994-96	79	43	66	98
Growth in consumption per capita (%/yr), 1987-96	-0.7	1.7	2.6	0.9
Percentage used for human consumption, 1994-96	73	95	30	17
Percentage used for animal feed, 1994-96	18	NA	56	66

Note: NA = Not available.
Source CIMMYT (1999).

Maize Breeding Research and Seed Supply

In eastern and southern Africa, as in other developing regions, seed of modern maize varieties reaches farmers through the efforts of many different organizations, including public national research institutes, public and parastatal seed production agencies, private multinational and national seed companies, public international agricultural research centers, NGOs, and farmer cooperatives. Over the years as the institutional and policy environment has evolved, some division of labor has emerged, and many of these organizations have become quite specialized.

Policies Affecting National Maize Seed Industries

During the 1980s and 1990s, many countries in eastern and southern Africa made significant progress in liberalizing and restructuring their maize sectors. Policy and institutional reforms targeted both output markets (markets for maize grain) as well as input markets (markets for maize seed). Reform of maize grain markets started earlier, however, and therefore has gone on longer.

The distinction between output and input markets is important, because reforms needed to restructure grain markets often differ from those required to induce desired changes in seed markets. In attempting to reform output markets, policy makers are interested mainly in the welfare of consumers, given the importance of maize as the major food staple for the vast majority of the population. In the case of input markets, policy makers are interested mainly in the welfare of producers, since improved maize seed is a key component of maize production technology. The distinction is to some extent arbitrary, however, because output and input markets are linked, directly and indirectly. For instance, efforts to help consumers by imposing a ceiling on grain prices represent a disincentive to maize farmers; if price controls reduce the profitability of maize production, farmers may respond by reducing the area planted, which in turn will depress the demand for seed and reduce availability of maize grain to consumers. Similarly, improved seed is an important input in maize production, the price of which directly influences production costs and hence farmers' income. Thus the availability and price of maize seed influence farmers' production decisions, which in turn affect the total supply of grain maize and determine its price and availability to consumers.

Given the importance of seed as a key technology component, the maize seed industry often receives special attention from policy makers (Tripp 1998, Pray and Tripp 1998). In eastern and southern Africa, as in many regions of the world, targeted institutional and policy provisions are in place to ensure that national seed industries perform well. For example, varietal registration and seed certification are mandatory in most countries, ostensibly to control the genetic and physical purity of commercial seed sold to farmers. Moreover, policies related to restricting or increasing participation in the seed industry, foreign investment and trade in commercial seed, price controls and intellectual property rights for protection of germplasm ownership are the norm.

How have national maize seed industries in eastern and southern Africa been affected by recent changes in the prevailing policy environment? Private seed companies are currently operating in all of the surveyed countries. The presence of an active private seed industry reflects a fundamental shift in policy, as private-sector participation was legally proscribed in most countries until recently. However, implicit restrictions limiting the participation of private seed companies are still in place in most countries. Barriers to entry faced by private firms include lengthy varietal registration procedures and mandatory seed certification requirements (Table 4).

One important policy change affecting national maize seed industries in all of the surveyed countries has been the lifting of restrictions on the importation of commercial maize seed. This change promises to be particularly beneficial for small countries in which the limited size of the seed market makes establishment of local seed production capacity uneconomic. It may also benefit countries in which multinational firms have refrained from selling their best hybrids for fear of losing the valuable inbred lines to competitors. In several countries, however, commercial seed imports are still subject to import

duties; if these duties are passed along in the form of higher prices, imported seed may be unaffordable for many farmers. While direct controls on maize seed prices have significantly diminished, governments in some countries continue to attempt to influence seed prices indirectly, for example by subsidizing the price of seed produced by public agencies.

The recent policy reforms are encouraging, but one area in which significant progress has yet to be made is in the area of intellectual property rights. As of 1998, no country in eastern and southern Africa was a signatory to the International Union for the Protection of New Varieties (UPOV) agreement, although several countries had enacted plant varietal protection laws or had extended patent protection statutes to plant varieties and/or plant genetic materials (Table 4). Yet even if intellectual property regimes relating to plant germplasm are still relatively undeveloped, some organizations are successfully using legal measures to appropriate benefits from investments in breeding research. For example, in Malawi, Mozambique, South Africa, and Tanzania, public research institutes collect royalties from private companies on the use of public varieties.

Table 4. Policies affecting national maize seed industries, eastern and southern Africa, 1998

Country/ region	Seed price control	Public seed production	Seed imports allowed	Mandatory seed certification	Plant variety protection laws on maize	Plant patents for maize	Varietal registration required	Average time needed for completing registration	Royalties on public material
<i>Eastern Africa:</i>									
Ethiopia	-	Yes	Yes	Yes	Yes	Yes	Yes	3	No
Kenya	-	No	Yes	Yes	Yes	Yes	Yes	3	No
Uganda	-	No	Yes	Yes	No	No	Yes	-	No
<i>Southern Africa:</i>									
Angola	-	-	-	-	-	-	-	-	-
Lesotho	-	Yes	Yes	Yes	No	No	Yes	0.5	No
Malawi	No	No	Yes	No	No	No	No	3	No
Mozambique	-	No	Yes	Yes	No	No	No	3	Yes
South Africa	-	No	Yes	Yes	No	No	Yes	2	Yes
Swaziland	No	No	Yes	No	Yes	No	Yes	1	Yes
Tanzania	No	No	Yes	Yes	No	No	Yes	-	No
Zambia	-	Yes	Yes	Yes	Yes	Yes	Yes	1.5	No
Zimbabwe	-	No	Yes	Yes	No	No	Yes	4	Yes

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

Structure of National Maize Seed Industries

Following widespread efforts to liberalize national seed industries, today there are only four public maize seed organizations operating in eastern and southern Africa, compared to 47 private seed companies (Table 5). Between 1992 and 1998, the number of public maize seed organizations decreased by nearly half, whereas the number of private maize seed companies more than doubled.

Changes in the relative numbers of public and private seed companies were reflected in a shift in the composition of seed sales. At the beginning of the 1990s, public and parastatal seed agencies accounted for most of the commercial maize seed sold in eastern and southern Africa, but by the latter half of the decade, private companies were supplying about 95% of the total amount sold (just over 90,000 tons were sold in 1996).

In the four countries that still have public seed organizations, only in Tanzania has the importance of the public seed industry declined in the face of growing competition from the private sector. In Angola, Ethiopia, and Uganda, public seed organizations continue to hold sizeable market shares, and private seed companies have made few inroads. The factors that have contributed to the continuing dominance of the public seed industry in these three countries are unique to each country. In Angola, the political atmosphere is not yet ripe for private seed companies to start doing business, mainly due to continuing civil strife. (The eight "private companies" listed for Angola in Table 5 are all NGOs, some of which distribute seed at no cost.) In Ethiopia, policy makers have been unusually reluctant to encourage the emergence of a private maize seed industry. In Uganda, commercial incentives needed to attract private-sector

investment have been lacking, and the only maize seed company currently in operation is a public seed production project based at Kwanda Agricultural Research Centre.

The data presented in Table 5 clearly show that except for the four countries mentioned earlier, during the 1990s the private sector assumed control of national maize seed industries throughout most of eastern and southern Africa. It is important to note however, that in several countries (e.g., Malawi, Zimbabwe, Zambia), the leading private seed company is merely a transformed version of what was previously a public or parastatal agency. Since often these public or parastatal agencies had enjoyed monopoly status, their privatization has left the national maize seed market heavily dominated by a single firm. Although the entry of additional private companies is expected to improve industry competitiveness in the future, currently the transformed parastatals remain in control of more than 80% of the national maize seed market in several countries.

The ability of the transformed state and parastatal seed agencies to maintain their dominant position can be explained by a number of factors. At the time of their privatization, these companies inherited well-established networks of seed growers, conditioning and storage facilities, distribution depots, and wholesale and retail distribution networks. Furthermore, these companies enjoyed (and in many cases continue to enjoy) a privileged relationship with the public research systems that have been the source of most of the popular commercial hybrids grown in the region.²

The situation is hardly static, however, and indeed the structure of many national maize seed industries continues to change. Since the initial wave of privatization, additional concentration has taken

² For a more detailed review of the evolution of maize seed production and marketing in eastern and southern Africa, see Rusike and Smale (1998), Rusike (1998) Howard and Mungoma (1997), Smale and Heisey (1997), Hassan and Karanja (1997), Rusike and Eicher (1997) and Eicher and Kupfuma (1997).

place in several countries as a result of mergers and acquisitions among private companies. Although industrial concentration could be beneficial if it allows seed companies to capture scale economies and to pass the resulting cost savings along to farmers in the form of lower seed prices, industrial concentration could also be harmful if it leads to reduced competition in the seed industry. Reduced competition could allow companies to engage in monopolistic pricing practices, which might threaten the affordability of improved maize seed for the small-scale, subsistence-oriented farmer.

Organization of Maize Research

Many countries in eastern and southern Africa feature very strong public maize breeding programs. Historically, these public breeding programs have played a crucial role in transforming local maize production practices. For example in Kenya, South Africa, and Zimbabwe, public maize breeding efforts began more than 50 years ago, and public breeding programs in these countries continue to be the main source of improved germplasm (see van Rensburg 1994, Byerlee and Jewell 1997, Eicher and Kupfuma 1997, Hassan et al. 1998). Until quite

Table 5. Maize seed organizations and seed sales, eastern and southern Africa, 1996

Country/region	Public seed companies				Private seed companies				Total maize seed sales in 1996 (t)	
	Number in 1992 ^a	Number in 1996	Percentage of seed sales in 1996	Total in 1992	Number in 1996			Percentage of seed sales in 1996		
					National	Multi-national	Other ^b			Total
Ethiopia	1	1	92	1	0	1	1	2	8	2,630
Kenya	0	0	0	1	2	2	1	5	100	17,220
Uganda	1	1	0	0	0	0	1	1	100	796
<i>Eastern Africa</i>	2	2	9	2	2	3	3	8	88	20,646
Angola	-	1	74	-	0	0	8	8	26	1,859
Lesotho	0	0	0	4	0	3	1	4	100	1,302
Malawi	0	0	0	2	1	1	1	3	100	3,140
Mozambique	2	0	0	0	1	0	0	1	100	1,780
South Africa	1	0	0	5	3	2	2	7	100	39,257
Swaziland	-	0	0	-	0	3	1	4	100	723
Tanzania	1	1	52	4	0	2	1	3	48	1,340
Zambia	1	0	0	1	2	1	1	4	100	2,600
Zimbabwe	0	0	0	4	2	2	1	5	100	19,000
<i>Southern Africa</i>	5	2	3	20	9	14	16	39	97	71,000
<i>Southern Africa, excluding South Africa</i>	4	2	6	5	6	12	14	32	94	31,743
<i>Eastern and southern Africa</i>	7	4	5	22	11	17	18	47	95	91,646
<i>Eastern and southern Africa, excluding South Africa</i>	6	4	9	17	8	15	16	40	91	52,389

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

^a CIMMYT (1994).

^b Mainly NGOs (in Angola and South Africa) and national seed dealers importing seed from multinational companies based in other countries (in the remaining countries).

recently, in almost all of the countries covered by the CIMMYT survey, public breeding programs were the only source of improved maize germplasm adapted to local conditions.

Traditionally, public breeding programs in eastern and southern Africa did not engage directly in seed production. Improved varieties released by public breeding programs were usually handed over to public or parastatal seed agencies, which multiplied seed for sale to farmers. The public and parastatal seed agencies often enjoyed a de facto legal monopoly; regulations restricting the participation of private companies in the maize seed industry were common in almost all countries (López-Pereira and Morris 1994).

Except for Lesotho and Swaziland,³ all of the countries covered by the CIMMYT survey currently feature public maize breeding programs that engage in varietal development activities (Table 6). Public and parastatal seed organizations no longer engage in varietal improvement research; the four public seed companies still in operation (in Angola, Ethiopia, Tanzania, and Uganda) have eliminated their research divisions and now serve exclusively as the seed multiplication arm of the national breeding program. Half of the private seed companies surveyed (14 out of 28) maintain in-house breeding programs and produce improved germplasm. The rest of the private companies that operate in the region either import seed from foreign affiliates or restrict themselves to multiplying seed of varieties developed by another branch of their company located elsewhere in the region.

Two international agricultural research centers that are members of the Consultative Group for International Agricultural Research (CGIAR) provide support to national maize research programs in Africa: CIMMYT and the International Institute for Tropical Agriculture (IITA). These two

centers, whose mandate is to strengthen and support maize research capacity in developing countries, have developed strong linkages with national maize research programs.

Since IITA focuses mainly on western and central Africa, CIMMYT has by far the stronger presence in eastern and southern Africa. Through offices in Ethiopia, Kenya, and Zimbabwe, CIMMYT provides direct and indirect support to national maize programs throughout the two regions. CIMMYT does not provide finished varieties intended for release directly to farmers. Instead, CIMMYT

Table 6. Number of public and private maize breeding programs, eastern and southern Africa, 1998

Country/region	Public agencies		Private seed companies	Total agencies surveyed
	Research organizations	Seed companies		
Ethiopia	1	0	0	1
Kenya	1	0	2	3
Uganda	1	0	0	1
<i>Eastern Africa</i>	3	0	2	5
Angola	1	0	0	1
Lesotho	0	0	0	0
Malawi	1	0	0	1
Mozambique	1	0	1	2
South Africa	1	0	5	6
Swaziland	0	0	0	0
Tanzania	1	0	0	1
Zambia	1	0	1	2
Zimbabwe	1	0	5	6
<i>Southern Africa</i>	7	0	12	19
<i>Southern Africa, excluding South Africa</i>	6	0	7	13
<i>Eastern and southern Africa</i>	10	0	14	24
<i>Eastern and southern Africa, excluding South Africa</i>	9	0	9	18

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

³ Swaziland's small public breeding program tests varieties released elsewhere (mainly in South Africa) to determine their suitability for Swaziland farmers.

develops and distributes intermediate germplasm products that are designed to be used as inputs into public and private breeding programs.

During the 1960s and 1970s, much of the maize germplasm provided by CIMMYT to national breeding programs in eastern and southern Africa originated from CIMMYT's breeding program in Mexico. After it became evident that materials developed in Mexico required substantial additional selection in order to become adapted to African production environments, in 1985 CIMMYT established a major regional research station in Zimbabwe to strengthen its maize breeding efforts in eastern and southern Africa. The function of the regional breeding program in Zimbabwe is to develop stress-tolerant, high-yielding maize germplasm adapted to the mid-altitude environments of eastern and southern Africa. Germplasm products of the CIMMYT regional breeding program include sources of resistance to prevalent biotic and abiotic constraints, open pollinated varieties, and inbred lines for use in hybrid formation.

Currently more than 100 seed shipments are distributed each year from the CIMMYT Harare program to breeding programs located throughout eastern and southern Africa. These shipments include more than 200 yield trials (each consisting of a set of elite varieties) and several hundred experimental lines. In accordance with standard CIMMYT policy, germplasm developed by CIMMYT is available free of charge to researchers in public and private breeding programs, both within the region as well as elsewhere throughout the world.

Public and Private Investment in Maize Breeding

Managers of public and private maize breeding programs contacted for the CIMMYT impacts survey were asked to provide information about human and financial investments in maize breeding research. In eastern Africa, the number of maize scientists employed in the public sector far exceeds the number employed in the private sector (Tables 7 and 8). In southern Africa, by contrast, the number of scientists employed in the two sectors is very similar. These numbers suggest that maize breeding in eastern Africa remains largely concentrated within the public sector, unlike in southern Africa, where private breeding programs have made considerable advances.

With regards to the intensity of research investment (measured here as the number of research scientists employed per million hectares of maize area planted), significant differences are evident by sector and region. Public research organizations in eastern Africa employ more than twice as many maize scientists per million hectares of maize area planted as public research organizations in southern Africa. This pattern is reversed in the private sector: private breeding programs have concentrated their investments in southern Africa, while largely ignoring eastern Africa.

What can be said about the productivity of maize scientists employed in the public and private sectors? Based on the average number of varieties released, scientists employed in the private sector have been twice as productive as scientists employed in the public sector, both in eastern and southern Africa.⁴ The figures can be expected to change, however, as the private seed industry matures. Since private seed

⁴ The figures in Tables 7 and 8 may understate the relative productivity of scientists working in the private sector, because the productivity measure for private-sector scientists takes into account only varieties being sold in 1998. By contrast, the productivity measure for public-sector scientists takes into account all varieties released between 1966 and 1998, a much longer period.

Table 7. Human resources invested in maize research, public sector, eastern and southern Africa, 1998

Country/region	Human resources in research (FTE) ^a				Number of non-research support	Total human resources	Number of scientists per million ha maize	Number of cultivars released per senior scientist
	Number of senior scientists	Number of junior scientists	Other	Total				
Ethiopia	3.0	14.0	60.0	77.0	0.0	77.0	1.7	4.0
Kenya	30.0	10.0	910.0	950.0	51.0	1,001.0	21.7	0.7
Uganda	2.0	2.0	14.0	18.0	0.0	18.0	3.6	1.0
<i>Eastern Africa</i>	35.0	26.0	984.0	1,045.0	51.0	1,096.0	9.4	1.0
Angola	3.3	11.0	3.0	17.5	5.0	22.5	5.0	2.0
Lesotho	0.5	0.5	1.2	2.2	3.4	5.6	2.7	0.0
Malawi	7.0	4.0	27.0	38.0	13.0	51.0	5.4	3.4
Mozambique	2.0	2.0	37.0	41.0	0.0	41.0	1.8	3.0
South Africa	20.0	0.0	40.0	60.0	0.0	60.0	5.3	0.4
Swaziland	0.0	6.0	25.7	31.7	0.0	31.7	0.0	-
Tanzania	11.0	0.0	18.0	29.0	81.0	110.0	6.1	1.6
Zambia	3.5	1.0	50.0	54.5	0.0	54.5	5.4	6.3
Zimbabwe	0.2	2.0	24.0	26.2	9.2	35.4	0.2	60.0
<i>Southern Africa</i>	47.7	26.5	225.9	300.1	111.6	411.7	4.4	2.2
<i>Southern Africa, excluding South Africa</i>	27.7	26.5	185.9	240.1	111.6	351.7	3.9	3.5
<i>Eastern and southern Africa</i>	72.7	52.5	1,209.9	1,345.1	162.6	1,507.7	5.0	1.9
<i>Eastern and southern Africa, excluding South Africa</i>	62.7	52.5	1,169.9	1,285.1	162.6	1,447.7	5.8	2.1

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

^a FTE = Full-time equivalents.

Table 8. Human resources invested in maize research, private sector, eastern and southern Africa, 1998

Country/region	Human resources in research (FTE) ^a				Number of non-research support	Total human resources	Number of scientists per million ha maize	Number of cultivars released per senior scientist
	Number of senior scientists	Number of junior scientists	Other	Total				
Ethiopia	-	-	-	-	-	-	-	-
Kenya	3.0	2.0	51.0	56.0	176.0	232.0	2.2	1.7
Uganda	0.0	0.0	0.0	0.0	65.0	65.0	-	-
<i>Eastern Africa</i>	3.0	2.0	51.0	56.0	241.0	297.0	0.8	2.0
Angola	-	-	-	-	-	-	-	-
Lesotho	-	-	-	-	-	-	-	-
Malawi	0.0	0.0	0.0	0.0	1.0	1.0	0.0	-
Mozambique	1.0	0.0	9.0	10.0	482.0	492.0	0.9	6.0
South Africa	35.0	11.5	155.5	202.0	227.5	429.5	9.3	1.9
Swaziland	-	-	-	-	-	-	-	-
Tanzania	2.0	1.0	11.0	14.0	209.0	223.0	1.1	2.8
Zambia	1.0	0.5	20.0	21.5	66.0	87.5	1.5	2.0
Zimbabwe	5.5	6.0	137.5	149.0	685.5	834.5	4.1	6.2
<i>Southern Africa</i>	44.5	19.0	333.0	396.5	1,671.0	2,067.5	4.1	2.9
<i>Southern Africa, excluding South Africa</i>	9.5	7.5	177.5	194.5	1,443.5	1,638.0	1.3	6.6
<i>Eastern and southern Africa</i>	47.5	21.0	384.0	452.5	1,912.0	2,364.5	3.3	2.9
<i>Eastern and southern Africa, excluding South Africa</i>	12.5	9.5	228.5	250.5	1,684.5	1,935.0	1.2	5.5

Source: CIMMYT Maize Research Impacts Survey, 1998/99.

^a FTE = Full-time equivalents.

companies are still relatively new in most countries of eastern and southern Africa, they have been releasing varieties at an unusually high rate in an effort to win a greater share of markets that have long been dominated by public agencies.

Investment indicators and productivity indices based on numbers of scientists can be misleading if they conceal significant differences in levels of financial support received by each scientist. Table 9 summarizes data on the cost of supporting senior maize scientists in the public and private sectors (salary and benefits, operating budgets). In both eastern and southern Africa, maize scientists employed in the private sector receive nearly twice as much financial support as maize scientists employed in the public sector. These data may explain the productivity difference between the public and private sectors; private-sector scientists produce twice as many varieties as public-sector scientists, but they do so with double the financial resources.

In interpreting the data relating to research investment and research productivity, it is important to remember that the average number of varieties released per scientist is not an ideal measure of research productivity, because all scientists may not have the same objectives. For example, scientists working in public breeding programs typically place greater emphasis on “upstream” research activities, such as population improvement, development of special trait materials, and other forms of “pre-breeding” work, whereas scientists working for private seed companies typically place greater emphasis on development of finished varieties. Furthermore, scientists working in the private sector are usually supported by well-established testing, production, and marketing systems, whose goal is to increase seed sales and maximize profits. By contrast, scientists working in the public sector normally face less pressure to increase sales and profits; instead, they are often encouraged to focus on activities that are expected to generate important social benefits.

Patterns of Maize Varietal Releases

The impacts of maize breeding research ultimately are felt when modern varieties are adopted and grown in farmers’ fields. Farm-level technology adoption decisions are affected by many factors that cannot be controlled directly by breeders, however, so varietal adoption rates provide an imperfect measure of breeding productivity. Widespread adoption of modern varieties indicates that breeding efforts have been productive, but lack of adoption does not necessarily mean that breeding efforts have been unproductive. In many instances breeding programs have developed excellent varieties, only to see adoption stymied by

Table 9. Cost (US\$/year) of supporting a senior maize scientist, eastern and southern Africa, 1998

Country/region	Public sector		Private sector	
	Salary and benefits	Operating budget	Salary and benefits	Operating budget
Ethiopia	3,429	-	-	-
Kenya	6,667	8,333	-	-
Uganda	5,100	-	-	-
<i>Eastern Africa</i>	5,065	7,276	-	-
Angola	3,117	-	-	-
Lesotho	-	-	-	-
Malawi	1,750	3,205	-	-
Mozambique	7,200	-	19,667	28,111
South Africa	31,915	51,643	50,531	-
Swaziland	19,557	-	-	-
Tanzania	1,440	-	12,000	24,000
Zambia	2,400	2,248	750	5,875
Zimbabwe	10,667	13,201	11,667	-
<i>Southern Africa</i>	9,756	12,161	18,923	11,597
<i>Southern Africa, excluding South Africa</i>	6,590	6,520	11,021	14,497
<i>Eastern and southern Africa</i>	7,410	9,718	18,923	11,597
<i>Eastern and southern Africa, excluding South Africa</i>	5,827	6,898	11,021	14,497

Source: CIMMYT Maize Research Impacts Survey, 1998/99.