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Maize in Eastern and Southern Africa: "Seeds" of Success in Retrospect*

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ABSTRACT

This synthesis revisits the "maize success story" in Sub-Saharan Africa, drawing selectively from an extensive published literature about maize seed technical change and related policies. The review focuses on the countries of Kenya, Zimbabwe, Zambia and Malawi, where maize is most important in the food economy, and refers to the period when maize became a dominant food croup through the 1990s.

The term "success" is equivocal in this case, both because of the difficulty of establishing the appropriate counterfactual and because some of the policies that contributed to success inone period later led to decline. While the "seeds" themselves were the result of innovative, successful maize breeding, boom periods in maize production were episodic and the public investments in the controlled markets that bolstered them were not fiscally sustainable.

Since maize will remain a crucial part of the food security equation even while the agricultural economies of the region diversify, continued investments in both maize research and market institutions, some of which must be public, are essential. The most vital question, however, is where the domestic political pressure to support these investments will originate – an issue related to governance.

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M. Smale and T.S. Jayne*

"The next stage in fact may well be to change maize in Kenya from a peasant subsistence food crop to one of the major raw materials of a country poor in many other raw materials and mineral resources. Land could be released for other cash crops in rotation with grazed pasture, leading to increased soil fertility instead of exhaustion from maize monoculture. New secondary industries could be generated to stimulate the country's economy. In fact, it is possible to envisage maize improvement causing an agricultural revolution as happened in the USA Corn Belt after the introduction of hybrid maize..."

M.N. Harrison, Chief maize breeder, Kenya (1970: 54)

"Inability to pay for seed and inability to sell product in a stable (and honest) market is the chief impediment to adoption of improved (and properly adapted) varieties, either private or public, in many developing countries....in Africa I fear that what was happening yesterday may not be a good predictor of what is happening today."

D.H. Duvick, (previously) Pioneer maize breeder, pers. comm.(March 13, 2002)

I. BACKGROUND

1.1. Definition of success

Though maize research and development was the most frequently cited success story among experts surveyed by Gabre-Madhin and Haggblade (2001), even a casual review of past work reveals that the term "success" is in this case equivocal. The story of maize seed research and development in Sub-Saharan Africa has been described as a "maize revolution" (Eicher and Byerlee 1997), a "qualified success story" (Eicher 1995), a "stop-and-go revolution" (Howard and Mungoma 1996), a "delayed green revolution" (Smale 1995), an "obscured revolution" (Gilbert et al. 1993), a "failure" (Kydd 1989), and a "cause of peasant impoverishment" (Page and Chonyera 1994). Each appellation refers to a specific period in time, location, and definition of success. Defining success is therefore fundamental.

There is little doubt that maize seed technical change has occurred in Sub-Saharan Africa. African smallholders have readily used well-adapted, modern maize types[1] in a number of locations and time periods, as documented historically by maize researchers and social scientists (the most recent broad compilation by Byerlee and Eicher 1997). Though percentages vary by year, in the late 1990s, an estimated 47 percent of all maize area in Sub-Saharan Africa and 58 percent in Eastern and Southern Africa was planted to modern maize (Morris 2001). Modern maize is estimated to represent more than three-quarters of maize area in Kenya,

[1] In this chapter, modern maize types refer to cultivars generated through adaptive on-station research, including either improved open-pollinated varieties or hybrids.

Zimbabwe, Swaziland, Lesotho, and South Africa. There is no doubt that as the land frontier diminishes in many parts of the continent, sustainable development in societies that remain primarily agrarian will require productivity gains rather than area expansion.

In this chapter, while we revisit some of the actors and technical ingredients that composed research "successes," we also seek to highlight the significance of the policies that promoted them. In particular, we ask whether seed technical change and associated policies enhanced (1) maize productivity; (2) farmer incomes; (3) equity; and (4) sustainability.[2] Using these criteria of "success", we draw purposively and selectively from a vast published literature about maize seed technical change, institutional development, and policy change in Sub-Saharan Africa. Viewing the case from a perspective that spans much of the 20th century, we seek to identify the factors that contributed to episodes of "success" as well as those that may have provoked periods of uncertainty and decline.

Defining the appropriate counterfactual for measuring success based on these criteria is exceedingly difficult, for three major reasons. First, the rate of growth in observed maize yields understates actual yield gains. Without continued infusions of improved seed, maize yields are likely to have declined over time due to pests and declining soil fertility, which would have made it even more difficult to meet food consumption requirements as the population grew (Gilbert et al. 1993). Second, separating yield changes due to genetic yield potential from those associated with changes in management practices is a methodological challenge, given their interactions, especially over larger geographical scales. Some practices, such as plowing in Zambia, have had negative long-term effects on the soil resource base (Haggblade and Tembo, 2002). Others, such as contour ridging in Malawi (Kettlewell 1965), protected the soil. Third, the rapid uptake of improved maize seed in Africa has involved a complex interaction between technological, institutional, and policy innovations. Technical change cannot be analyzed separately from changes in the institutional and policy environment, and it is nearly "impossible to separate the relative influences of technology, human capital, and institutional innovations with much accuracy" (Bonnen 1990: 263).

1.2. Scope

The documented history of maize in Africa spans the 20th century, but our focus is the second half, when the establishment of formal planting breeding institutions on the continent resulted in the systematic release of improved open-pollinated maize varieties (IOPVs) and maize hybrids. We have defined three key historical phases. During the 1900-1965 period, maize became the dominant food crop in case study countries. Smallholder maize production expanded during the second period, after Independence, which occurred in distinct calendar years and global economic contexts in each case study country. We label as "uncertain" the third period, from 1990. The past decade has been characterized by a combination of unfavorable weather conditions, declining public investments in agricultural research, subsidy reductions, and erratic policies, which appear to have precipitated a decline in maize productivity (national maize yields and production) in case study countries.

Our case study countries are Kenya, Malawi, Zimbabwe, and Zambia, though we also identify cross-cutting themes drawn from Nigeria, Ghana, and Ethiopia (Box 1). Selection of countries reflects the relative importance of maize in the food economy, as measured in terms of the percent of total cereal area, per capita consumption, extent of direct use as a staple food (Table 1). Among the largest maize producers in Eastern and Southern Africa, maize occupies 75 percent or more of cereal area only in Kenya, Malawi, Zambia and Zimbabwe. The largest

[2] We use these terms as defined in chapter 1.

maize producers in Western Africa are Nigeria and Ghana, though the average percentage of maize used for human consumption is considerably lower there than in most of eastern and southern Africa. The average per capita consumption of maize as food is over 94 kg/yr in Kenya, over 100 kg/yr in Malawi, Zambia, and Zimbabwe, and a mere fraction of that level in Ghana and Nigeria.

1.3. The Challenge of Maize

There are several properties of maize as a crop species that influence the nature of seed genetic change and therefore the likelihood of achieving any impacts on the welfare of smallholder African farmers through yield increases. These are aptly summarized by Morris (1998 and 2001) and Pandey (1998), on which the following is based.

Maize is predominantly a cross-pollinating rather than a self-pollinating species. When rates of cross-pollination are high in a crop, genetic material is exchanged when pollen flows among neighboring plants. Unless carefully controlled, all of the maize plants in a given field will differ from the preceding generation and from each other. When maize self-fertilizes, the progeny often have undesirable traits, but when it cross-fertilizes, some demonstrate significant yield advantages relative to their parents (termed "hybrid vigor"). Maize is the world's most widely grown cereal, cultivated across a range of latitudes, altitudes, moisture regimes, slopes and soil types, with the simplest to the most mechanized production technologies.

High rates of cross-pollination means that the attribution of yield increases in farmers' fields to specific introductions of improved seed (either of improved open-pollinated varieties or of hybrids) is more difficult than it is for other major cereals like rice or wheat. The advantages of F1 seed of maize hybrids can degenerate rapidly when farmers save the seed and replant it, though evidence suggests that in some cases advanced-generation hybrids significantly outperform the variety that the farmer was growing previously—depending on the type of hybrid and the control that serves as the basis for comparison (Morris, Risopolous and Beck 1999). Due to market imperfections and cash constraints, African smallholders often "recycle" F1 seed.

Hybrid vigor in maize means three very important things for African smallholder farmers. First, it means that to sustain the yield increases they seek, they are reliant on a seed industry in a way that neither the rice nor wheat farmers of Asia's green revolution ever have been. On the other hand, a hybrid-based maize sector also requires large-scale commercial seed enterprises, whose profits can be sustained only by strong seasonal demand by farmers for renewing their seed (Tripp 2001). Furthermore, temperate maize germplasm is not easily adapted to the non-temperate environments of the developing world—so that the gains achieved by private companies in the U.S, Europe, and some parts of China are not easily transferred to many of the smallholder farmers who produce in the wide range of microclimates and technologies found in the developing world (Morris 2001).

II. MAIZE BECOMES A DOMINANT FOODCROP (1900 - 1965[3])

There is no evidence of maize cultivation in Africa until the 16th century (Miracle 1966), when it was introduced from the Americas to Africa along the western and eastern coasts, gradually moving inward as a ration with the slave trade.

Before 1965, the rise of maize production in all of the case study countries was propelled to a greater or lesser extent by five driving factors: (1) the agronomic suitability of maize (2) the British starch market; (3) milling technology; (4) the integration of Africans into the settler wage economy; and (5) market and trade policies promoted by settler farm lobbies.

2.1 Agronomic Suitability

Millet and sorghum were the staple foods of Africans at the beginning of the century. However, maize was regarded as "eminently suitable" (Anthony 1988) for mixed farming by pioneers because 1) it required less capital investment and technical skill than did cotton and tobacco (and could therefore be produced by newly arrived novices), and 2) it gave higher returns to land than other indigenous cereals under reasonably favorable conditions, though not throughout the entire range of ecological conditions (Weinmann 1972; Harrison 1970: 22). Maize's transition to a major crop in Kenya occurred during World War I, when disease in millet led to famine and millet seed was consumed rather than planted. In Zimbabwe, white settlers began producing maize as early as the 1890s (Byerlee and Heisey 1997). Howard (1994) reports that maize was a staple in Northern Rhodesia's Luapula Province by the end of the 1700s, though it is fairly certain that "there are no large areas where maize was more than a minor food at the beginning of this century" (Miracle 1966: 156). Maize did not dominate in Malawi until well into this century (Williamson 1956).

Long term weather patterns and soils maps suggest that much of Malawi's growing environment has long been favorable for rainfed maize (Heisey and Smale 1995, p.5), as are a number of environments in Zambia, Kenya, and Zimbabwe. Returns to labor are likely to have been higher for maize. Maize is protected from bird damage by its leafy covering, while the exposed grain of sorghum and millet requires labor time for scaring birds. When off-farm wage employment became important for Africans, these agronomic features of maize provided further advantages compared to small grains (Low 1986).

2.2 The British Starch Market

Until the 1920s, export volumes exceeded human consumption as the major destination of the maize produced by settlers in Kenya and Zimbabwe. Ironically, the preferences of today's African consumers for white as opposed to yellow grain color began with the influence of the British starch market during these years.

As early as 1911, increasing demand and price premia were evident for white maize in the British starch market, apparently because North American producers of yellow maize had a decisive transportation cost advantage in supplying Britain (Masters 1994). Since the British starch market provided a premium for white maize, local legislation was passed in some parts of

[3] Prior to the transition to majority rule in 1966 and 1980, respectively, Zambia and Zimbabwe were known as Northern and Southern Rhodesia, respectively. Malawi was known as Nyasaland. For simplicity, this chapter refers to these areas by their current names.

the region requiring that only white maize be accepted for export. Though both white and yellow maize varieties of maize were grown, settler farmers were informed by the Secretary of the London Corn Exchange that exports required better grading and uniformity (Weinmann, 1972, pp. 19-20). Farmers discovered that when yellow and white maize were grown in close proximity and cross-pollinated, the grains of the progeny was mixed in color, rendering it unsuitable for export. The Rhodesian Maize Authority passed a resolution in 1923 stating that the introduction of yellow maize varieties into the territory posed “a vital danger to the maize growing industry.” In Zimbabwe, the Maize Act (1925 to 1970), enabled growers to petition the Government to restrict the growing of maize in their area to a specific variety and color (Jayne et al 1995).

Emphasis was also given to the soft dent-type maize favored by the British starch market, as this was easier to process and less injurious to industrial roller mills (Kydd 1989). By 1920, both smallholder and commercial farmers in Zambia and Zimbabwe had largely replaced their white flint cultivars with improved white dents, though these may also have been higher-yielding (Jayne et al 1995).

2.3. Integration of Africans into settler wage economy

The grafting of mines, plantations, and cattle enterprises onto the local economy expanded the demand for food in the country. Eventually the domestic demand for maize grew as Africans left their farms to work on settler farms, in mines or industrial plants, particularly in Kenya, Zambia and Zimbabwe (Mosley 1983; Jansen 1977). Food consumption preferences were influenced by the rations that employers used as in-kind payments. Diets adapted in a self-generative process, as “people got used to what they consumed"(Shopo, 1985).

By the 1920s, maize accounted for approximately 80 and 60 percent of the settler cropped area in Zimbabwe and Zambia, respectively, and provided in-kind payments for the rapidly increasing African labor force. By contrast, Malawi had the smallest extent of land in the former British Central Africa but the largest concentration of peoples (Pachai 1973). An exporter of African labor to the mines of the Rand and farms of Zambia and Zimbabwe (Tindall, 1968), Malawi had few areas with elevations high enough to attract a European population easily decimated by malaria (in contrast to Zimbabwe) and no rich mineral deposits (in contrast to Zambia). Consequently, Malawi never developed an organized settler constituency, a distinction that has led to a different trajectory in maize research and maize consumption preferences.

2.4. Settler Lobbies, Market Control, and Trade

The threat of competition from African farmers led colonial administrations to design and implement of controlled marketing systems from the 1930s. Evidence from Kenya, Zambia, and Zimbabwe indicates that African farmers were capable of generating maize surpluses at prices below the production costs for most settler farms, and that settler farmers successfully lobbied colonial legislatures for protection (Jayne et al 1995). Initially, in both Kenya and Zimbabwe, settler consumer interest groups such as animal feeders, mines, and plantation farmers strongly opposed protection for settler maize farmers on the grounds that it would raise the cost of maize (Keyter 1975; Mosley 1975). Over time, however, settler maize producers' interests were increasingly well represented in the colonial legislatures. Catalyzed by slumping world agricultural markets during the 1930s depression, the colonial governments passed the Maize Control Acts of the 1930s in Zimbabwe and Zambia, and the Native Produce Ordinance in Kenya in 1935.

These marketing acts (1) created state crop-buying stations in European farming areas without parallel investments in African farming areas; (2) enforced a two-tiered pricing scheme with higher prices for settler farmers than for native Africans; and (3) established restrictions on grain movement from African areas to towns, mines and other demand centers. From 1935, the combination of maize legislation, land evictions, and fiscal policies weakened Africans' position in food marketing relative to that of settler farmers in Kenya, Zambia, and Zimbabwe (see Figure 1 for evidence in Zimbabwe; see also Mosley 1983; Jayne et al 1995).

The rise of centralized, state maize marketing boards also encouraged the development of large-scale, concentrated grain milling industries, using roller mill technology first employed on a large scale in Kenya, South Africa, and Zimbabwe in the 1950s. Controls on private maize movement provided the licensed roller millers (that produced a refined and more expensive type of meal) with a *de facto* monopoly on maize meal sales to cities and grain-deficit rural areas once local supplies were exhausted (Jayne et al 1995).

This system of market regulation was effective in achieving its principal objectives. Settler maize production expanded and producers earned prices that generally exceeded export parity. Kenya and Zimbabwe (except during World War II) remained reliably self-sufficient in maize. Through discriminatory pricing made feasible by controls on marketing, the cost of supporting settler maize production was paid largely by African farmers and consumers rather than European taxpayers, making the system fiscally sustainable (Jayne and Jones 1997). Opposition to agricultural price supports was accommodated by selective consumer subsidies. The stability of the policy and pricing environment (and the limited competition faced by industrial mills) contributed to rapid growth in commercial agriculture, the demand for maize research and later, the adoption by commercial farmers of hybrid maize varieties developed by national research systems.

2.5. Milling technology

African maize production received a boost with the introduction of the hammer mill in the 1920s (Shopo 1985). Hammer mills gave a processing cost advantage to maize over small grains, since maize could be dumped into the hopper for grinding, while millet and sorghum husks required de-hulling first.

The prevalence of large-scale, industrial processors in Kenya, Zambia and Zimbabwe contributed to preferences, particularly in urban areas, for dent types. The removal of the germ and pericarp makes refined meal look whiter, last longer, and taste sweeter than whole meal. Hammer-milled, whole meal remains the primary staple food in the grain self-sufficient rural areas of these countries. Though they also consume whole meal in rural areas, Malawi's population has long expressed a strong preference for maize porridge made from "ufa woyera" (white, almost iridescent, flour). The fact that Malawi's population remained predominantly—and densely—rural may explain the persistence of other processing methods.[4] Maize flour in rural areas of Malawi is processed with a combination of hammer-mill technology and several stages of pounding by hand, soaking, washing, and drying (Kydd 1989, Ellis 1962).

2.6. Early maize research

[4] The appropriate technology depends in part on the opportunity cost of women's labor, since grain processing has been viewed as a woman's task in most of Southern Africa (Bagachwa 1992).

The investments by colonial government and settlers themselves in the maize research that radically transformed maize production in Kenya and Zimbabwe began as early the 1930s, "soon after the news of the great success of hybrid breeding in the USA began to be widely known" (Harrison 1970: 28). In 1919, commercial farmers in Zimbabwe founded the Maize Breeders Association (Rusike 1998). Zimbabwe's maize breeding program, initiated by H.C. Arnold in 1932, was the first outside of the U.S. to produce double-cross hybrids for commercial use, releasing Southern Rhodesia-1 (SR-l) in 1949. The team then turned their attention to single-cross hybrids, which have a greater yield advantage and are more uniform in the F1 generation, though their seed is more costly to produce. In 1960, they released the first commercially grown single-cross hybrid in the world, SR-52 (Rusike 1998: 306).[5] "The combination of SR-52 seed, fertilizer and improved agronomic practices increased maize yields 46% over Southern cross, the most common improved local variety" (Eicher 1995). SR-52 diffused rapidly and widely among commercial farmers, becoming one of the most popular hybrids in the region and a parent of many others.

Before independence, Zambia relied on its Federation partner Zimbabwe for improved maize germplasm, and the importation and use of SR52 (as well as other hybrids) is said to have doubled commercial farmer yields from 1949-53 levels of 1.3 t/ha to 2.7 t/ha 1959-63 (Howard 1994). The preferences of Malawi's smallholder farmers and the superior on-farm processing rates of Malawi's flint maize types relative to dents were recognized by Malawi's first maize breeder, R. T. Ellis (1954, 1962), who developed several synthetics as well as a flint hybrid LH11 before his resignation in 1959.

The first scientific maize research program in Kenya began in 1955 in Kitale, the center of maize production in the White Highlands. The first modern maize type released in Kenya, Kitale Synthetic II (an IOPV released in 1961), was based on inbreds developed from the Kenya Flat White complex of farmers' selections. M.N. Harrison, chief Kenyan maize breeder, felt "the need to widen the genetic base of the Kitale program," and while "nothing of value" had come from earlier testing of U.S. Corn Belt, European, South Africa, Rhodesian, and Australian materials, "the great diversity of center-of-origin material from similar ecological conditions to those of East Africa, close to the Equator with a wide range of altitude, had never been tried"(Harrison 1970: 38). In 1958 he returned from a trip to Mexico and Colombia, funded by Rockefeller Foundation, with exotic breeding material (Anthony 1988). After screening 124 test top-crosses of these materials with Kitale Synthetic II, the outstanding result was a cross with an unimproved Ecuadorian landrace (Ecuador 573). Released in 1964, the varietal hybrid (Hybrid 611) made from Kitale Synthetic II and Ecuador 573 was the basis of all hybrids developed since by the national (Hassan et al. 1998). The yield advantage of this unique varietal hybrid over Kitale Synthetic II was 40 percent (Gerhart, 1975: p. 5). Varietal hybrids have lower seed costs than conventional hybrids, with lesser loss of yield advantages when recycled. Released on the eve of Independence, H611 diffused among large- and small-scale farmers in the high potential areas of western Kenya "at rates as fast or faster than among farmers in the U.S. Corn Belt during the 1930s-40s "(Gerhart, 1975: 51).

[5] Breeding records indicate that Pioneer first released single crosses as named hybrids in 1961, though small U.S. companies mostly likely released them before 1960 (Duvick, pers. comm.).

III. EXPANSION OF SMALLHOLDER MAIZE FROM 1965 [TO 1990]

By the time of transition to majority rule in Eastern and Southern Africa, maize became the cornerstone of a "social contract" that the post-independence governments made with the African majority to redress the neglect of smallholder agriculture during the former colonial period (Jayne et al 1999). The controlled marketing systems inherited by the new governments at independence were viewed as the ideal vehicle to implement these objectives

The benefits of controls for settler farmers during the colonial period generated the belief that the same system could also promote the welfare of millions of smallholders if it were simply expanded (Jenkins 1999). The social contract meant that governments were responsible for ensuring food self-sufficiency in white maize at a cheap price. Because the world market for white maize is thin, domestic production shortfalls often necessitated imports of yellow maize, an inferior substitute that connotes agricultural policy failure (Jayne and Rukuni 1993).

Each of the case study countries achieved impressive episodes of maize production growth, driven by interacting innovations in technology, policies, and institutions. We mark these growth episodes as: 1965-1980 in Kenya; 1970-1989 in Zambia; 1980-89 in Zimbabwe, and 1983-93 in Malawi. Some of the ingredients of these episodic successes retain continued importance, while others could not be sustained, and may have contributed to the uncertainty of the 1990s.

Good germplasm through innovative breeding was the essential ingredient of each episode of success. Though each has other, unique ingredients, all share: (1) complementary investments in agronomic research, extension, seed distribution systems, and rural infrastructure; and (2) institutions to coordinate grain marketing with seed, fertilizer and credit delivery. This second ingredient, however, was implemented through controlled pricing and marketing systems that incurred large subsidies and treasury costs, and which eventually contributed to fiscal crisis. The points reported below synthesize findings from a set of detailed theses and studies analyzing the causes of seed technical change in smallholder maize production during the relevant time periods (Gerhart 1975; Karanja 1990; Hassan 1998); Zimbabwe (Rohrbach 1988; Rusike 1995; Eicher and Kupfuma 1997); Zambia (Howard 1994; Howard and Mungoma 1996); and Malawi (Smale 1994; Heisey and Smale, 1995).

3.1. Maize Germplasm

There is little doubt about the quality of the germplasm products released by Kenya's maize research program in the early years. Research breakthroughs were accomplished first and foremost because of the capacity and continuity of the Kenya maize program staff, which was "probably unmatched in any national research program in Africa" (Gerhart 1975), a program which remained public. From its inception in 1955 to 1973, the maize breeding program had only two directors, M.N. Harrison and F. Ogada. During those initial years, the Rockefeller Foundation and USAID facilitated the exchange of germplasm between continents as well as the sharing of new research experience concerning hybrid genetics. (Gerhart, 1975; Harrison 1970; Anthony 1988). The four Kenyan maize programs (Kitale, Embu, Katumani, and Mwtapa) have since released a succession of hybrids and improved open-pollinated varieties, and one of the greatest achievements has been the release of a range of materials to suit the nation's diverse agroclimatic conditions (Hassan 1998; Karanja 1990).

Similarly in Zimbabwe, "small teams of highly motivated and well-paid local scientists" devoted their entire careers to maize research (Eicher and Kupfuma 1997: 35-37), backed by the revenues earned and contributed by commercial farmers. The second major episode of maize seed technical change in Zimbabwe occurred following independence in 1980 among smallholder farmers of the previously "communal" areas, largely based on R200, R201 and R215. Suitable for production on sandy soils in low rainfall areas, these short-season maize hybrids were bred by Nelson for settler farmers seeking to diversify from tobacco exports when the Unilateral Declaration of Independence (UDI) was declared in 1965. Though three-way crosses are in general relatively uniform and intended for annual purchase and higher levels of management, they may still perform well relative to unimproved types when grown with fairly low levels of management. Like SR52, the R-200 series were later popular among smallholders in neighboring countries. Not until the change to majority rule in 1980, however, did smallholders acquire widespread access to the germplasm and complementary inputs. Earlier, smallholder use of modern maize would have occurred spontaneously as a result of native Africans' interaction with commercial, settler farmers, but not as part of a systematic, nation-wide effort. Estimates in the literature suggest that between 20 and 40% of Zimbabwe's smallholders in communal areas grew maize hybrids during the 1970s (Rohrbach 1988; Kupfuma 1994

The germplasm produced by the Zambian maize program from the mid-1970s through the early 1990s included an impressive array of 10 double and three-way crosses bred by Ristanovic, and 2 flint-type, early-maturing, IOPVs bred by Gibson (Howard 1994; Howard and Mungoma 1996). In all but the most difficult growing environments, the hybrids outyielded local (and improved) open-pollinated varieties even without fertilizer. Unlike the single cross SR52, they were double and three-way crosses, so their yield advantages lost with recycling were not so great. Meanwhile, the very early maturing, drought-tolerant, flinty IOPVs were used as an early food source as green maize (Howard 1994). As in the Kenya and Malawi cases and to a far lesser extent the Zimbabwe case the advances depended on access to both international breeding expertise and germplasm collections.

Malawian smallholders waited much longer for suitable hybrids. One reason was discontinuity in staffing and funding—accompanied by shifts in emphasis between hybrids and IOPVs (Kydd, 1989). Another constraint was scientific, since local flint materials were too tall, regional breeding had focused on dents, and exotic flint germplasm with suitable characteristics was not easy to identify. Malawi did not have the dense urban populations to feed that preoccupied Zambian leaders, and neither the settler farmers nor Malawian smallholders had a political voice (Smale 1995). In 1990, B.T. Zambezi, E.M. Sibale, and W.G. Nhlane released the national program's first adapted, semi-flint hybrids, MH17 and MH18. These were top-crosses of Malawian lines and flint populations from CIMMYT. Three aspects of the semi-flint top-crosses made them a success. First, semi-flint, top-cross hybrids were well suited to production by smallholders who process and consume their grain on farm and recycle their hybrid seeds (Zambezi et al. 1997; Benson 1999). Farmer evaluations (Smale et al. 1993) and experimental results demonstrated that that these semi-flint hybrids could be processed on the farm like local flint types (Box 2). Second, trial and demonstration results showed that there were only minor differences in yield among the various Malawi hybrids, so that yield was not sacrificed for grain texture. Third, analysis of trial results and extensive demonstration data for three of the major maize producing zones (representing 70% of Malawi's maize area) during the 1989/90-1991/92 seasons showed that unfertilized hybrid maize yields were higher than those of unfertilized local maize, even during the worst drought year in decades (Heisey and Smale 1995).

3.2 Complementary investments

Harrison (1970) and Gerhart (1975) both attributed successful diffusion of improved maize seed in Kenya not only to good maize germplasm, but to a sound agronomic research, effective linkages of research to extension, a strong commercial seed enterprise, and the coordination of input and maize marketing. The Kenya Seed Company (KSC) was formed by large-scale farmers in 1956 but entered into an agreement with the Kenya government to produce and distribute maize seed in 1963 (Karanja 1990), employing stockists who were "small-scale African storekeepers selected for their location, reputation, and interest." The approach, modeled on the marketing of Wilkinson razor blades, was "every stockist an extension agent" (Gerhart 1975: 9). Credit was used only at the discretion of individual stockists. Like Harrison, Gerhart (1975) emphasized that the Kenya Maize Research Program had never been isolated from the other components of a national maize program. These included, as early as the 1960-70s, a relatively dense transport network, crop research, marketing boards offering guaranteed prices, and an extension service. In 1965 the extension services reputedly planted 5,000 demonstrations, followed by hundreds of fertilizer demonstrations. Gerhart's survey revealed that extension agents were the first source of information about hybrid seed, followed by other farmers.

The second major phase in Zimbabwe's maize revolution (Eicher 1995) occurred from 1980 to 1988, following the end of the civil war in 1980. Much of the institutional foundation that fueled the 1980s smallholder growth episode was inherited from the colonial period. Private sector maize seed production began in 1940 when settler farmers established the Seed Maize Association of Southern Rhodesia, which successfully met the needs of its clients (Rusike, 1995). In 1979, the Seed Maize Association was converted to the Seed Maize Cooperative, administered by the powerful Commercial Farmers Union, and organized as a cooperative in order to transfer monitoring and inspection costs from the government to members, as well as to avoid taxes and profit distributions (Rusike, 1995). Seed Co-op was created in 1983, and continued to enjoy autonomy from the government at the same time that it benefited from tax breaks, exclusive rights to some seed types, and access to subsidized credit (Rusike, 1998). When the civil war ended in Zimbabwe, the new government attempted to expand the input delivery, credit, and marketing programs that had previously served only large-scale producers (Blackie, 1990; Rohrbach 1988). Rohrbach (1988) attributes the tripling in smallholder maize production that occurred from 1980 to 1988 to five factors: (1) the ending of the independence war in 1979; (2) an increase in the use of hybrid maize seeds from about 40% in 1979 to 98% by 1985; (3) an increase in state crop buying stations serving smallholder areas, from five in 1980 to 148 in 1985, thus reducing the costs and risks associated with producing maize for the market; (4) an eight-fold rise in in-kind credit allocated to smallholders between 1979 and 1986, which stimulated fertilizer use and maize yields; and (5) an associated response by private input suppliers to the increased demand for farm inputs.

In addition to maize germplasm, Howard (1994) and Howard and Mungoma (1996) identified as driving factors Zambia's land surplus, favorable weather, and the heavily subsidized state-led system of credit, input, and maize marketing support to smallholders. SIDA, which funded maize research from the 1980s, also funded the establishment of a seed industry, including Zamseed and the Seed Control and Certification Institute. Zamseed produced all seeds as a commercial company, though the government and SIDA owned large shares (Cromwell 1996).

Several structural factors other than germplasm contributed to sharply rising smallholder adoption rates in Malawi from the mid-1980s until 1993, as indicated by the fact that use of hybrids with dent grain texture rose in the years preceding the release of the semi-flint, top-crosses. Primary among them was a supply of quality commercial seed, which had been a binding constraint in the early years of Malawi's maize breeding program. National Seed Company of Malawi (NSCM) took responsibility from ADMARC in 1978, and Cargill acquired most of the equity of NSCM in 1988, with a more aggressive approach to seed production, procurement and marketing. Price ratios were also favorable for the use of hybrid seed and fertilizer during the late 1980s in Malawi (Smale and Heisey 1994: 699). Seed prices also dipped in that period, likely in response to large inventories held by NSCM after years of low use of hybrid seed.

3.3. Coordinated input and grain markets

The objectives of the newly independent governments (stated above) were addressed in all four case study countries through similar mechanisms. These mechanisms enhanced the profitability of growing maize by smallholders, stabilized net returns in a variable rainfed growing environment, and encouraged maize consumption by urban and rural consumers.

First, the expansion of state marketing infrastructure in smallholder areas facilitated the disbursement of credit and subsidized inputs to smallholders by state agencies designed to recoup loans through farmer sales to the marketing boards (Rohrbach 1988; Howard 1994; Jabara 1984; Kaluwa 1992; Smale 1994). Second, both direct and indirect input and credit subsidies supported maize production. For example, fertilizer subsidies in Zambia averaged 60 percent of landed cost by 1982—with 90 percent of fertilizer used on maize (Williams and Allgood 1991). In addition to the direct subsidy, an expanded network of cooperative marketing depots reduced the transactions costs of selling maize in remote areas. In Malawi, ADMARC (Agricultural Development and Marketing Corporation) assumed an all-encompassing responsibility for delivering inputs for the production of the staple food, marketing of maize output, stabilizing maize prices through maintaining storage facilities, and transporting maize into food-deficit areas during the hungry season. Third, pan-territorial pricing brought smallholders in remote areas into production for state markets and assured a national crop but distorted regional advantages. Finally, in some cases and periods, as in Zimbabwe from 1980 through 1998, maize producer prices were guaranteed by the state at well above export parity prices.[6] At the same time, most governments subsidized the retail price of industrial maize meal to consumers, thereby raising the demand for domestic production under a policy of maize self-sufficiency.

However, in all four countries, marketing board costs escalated as the scale and complexity of their activities increased. Losses consisted of two types: those which government forced on the board by mandating it to carry out activities that were unprofitable but fulfilled "social" functions like buying maize at above-market prices in remote areas (which encouraged maize production expansion), and those related to operational inefficiency (which probably had little effect on smallholder maize production). Pan-territorial pricing was particularly burdensome in Zambia and Zimbabwe, since it raised the share of grain delivered to the boards

[6] This conclusion flows from the GMB's annual maize trading account statements showing losses on maize exports to regional neighbors during this period.

by smallholders in remote (but often agronomically high-potential) areas where transport costs were high (Bryceson 1993, GMB 1991). Stockpiling white maize, a consequence of government preoccupation with maize self-sufficiency, was also costly (Buccola and Sukume 1988; Pinckney 1993). Operational inefficiency varied across countries, though it appears to have been greatest in Zambia and Kenya (Amani and Maro 1992; Scott 1995; Bates 1989). Allegations of corruption were widespread, even in Zimbabwe's relatively efficient Grain Marketing Board (CSM 1986). In some cases, the treasury costs of state marketing operations were so large that they affected rates of inflation, interest, and currency exchange, especially in Zambia during the 1980s (Jansen and Muir 1994).[7]

Other distortions resulted at the farm level. Packages were often of fixed size and input proportions that were not optimal for all farmers. Farmers had little choice concerning seed source or type, and grew what was available in that year from a single source, while often seed was effectively rationed since certain quantities were reserved for credit club members (Cromwell and Zambezi 1993; Smale et al. 1991). Farmers near urban demand centers who were implicitly taxed through pan-territorial pricing resorted to parallel markets. Declining volumes through the state marketing channels further exacerbated the boards' trading losses. In turn, the increasing proportion of maize sales by smallholder farmers, generally on poorer land with less reliable rainfall, increased the instability of marketing board purchases and sales, and hence of the fiscal demands made by the marketing system. Controls on private grain movement, imposed by the earlier colonial governments, were continued in all countries even after independence. These controls also prevented grain from flowing directly from surplus to deficit rural areas (Jayne and Chisvo, 1991; Odhiambo and Wilcock 1990). Official restrictions on private trade and weak market infrastructure often made it easier for surplus farmers to sell to the Boards rather than their deficit neighbors a few kilometers away (Jayne and Chisvo 1991). Finally, a growing body of empirical evidence pointed to the controlled marketing systems as suppressing or imposing additional costs on parallel trading and processing channels that often served the interests of both producers and consumers more effectively than the official state apparatus (Rubey 1995; Amani and Maro, 1992).

A major difference in implementation of pre- and post-independence maize policy was the method of supporting food production growth. The colonial governments in Zimbabwe and Kenya in particular drew the resources to support a relatively small, privileged group of settler farmers largely from consumers and African farmers, through discriminatory pricing schemes. By contrast, the post-independence governments drew the resources primarily from the treasury when they attempted to lavish the same level of support to a much wider African farmer and consumer constituency. In most cases, the treasury and aid donors bore most of the cost of expanding marketing services to smallholders, and the system was not fiscally sustainable.[8]

[7] For example, Kenya's National Cereals and Produce Board accumulated losses equal to 5% of GDP in the 1980s. And Zambia's National Agricultural Marketing Board's operating losses were roughly 17% of total government budgets in the late 1980s (Howard and Mungoma 1994).

[8] During this phase of marketing policy, donors helped cover the operating losses of the state marketing system, as in Malawi. Donors also provided extensive support to the expansion of government bulk grain handling facilities, which yielded little direct benefit to smallholders but added substantially to the marketing board costs (Jones 1994).

IV. THE PERIOD OF UNCERTAINTY (1990s)

We have identified four major factors that contributed to lower rates of growth in maize production and maize yields during the 1990s: (1) weather instability (2) contraction of state subsidies and market support (3) declining investment in public agricultural research, combined with uneven progress in liberalizing the maize seed industry, and (4) crisis-motivated maize policies.

While the first factor constituted an "exogenous shock" for all actors involved, the remaining three are evidence that governments "reneged" on the social contract of the post-independence period, choosing short-term panaceas over longer-term policy solutions. The 1990s brought much tighter fiscal constraints on government social activities, due largely to the treasury deficits accumulated during the maize boom periods and to donors' unwillingness to continue supporting them. As explained further below, tighter fiscal constraints during the 1990s led to a new series of government and donor programs that still served important political ends but provided less commitment to the long-term public investments needed to sustain rural productivity over time.

4.1. Weather

Maize yields are considerably more variable in Southern Africa, and particularly in Zimbabwe, than in other parts of the world (Byerlee and Heisey 1996). But weather during the past decade probably has accentuated yield instability. Meteorological data from 1914/15 to 2000/01 in Zimbabwe indicates that five of seven stations received at least 15% lower cumulative seasonal rainfall over the last decade than in the previous eight decades. Drought beset the country in 1992/93, 1994/95, and 1997/98. The early 1990s in Malawi were characterized by frequent drought or mid-season dry spells, with the 1991/2, 1993/4 and 1994/5 seasons all being poor for maize. In particular, the drought in 1991-92 devastated maize production in Zambia, Zimbabwe, and Malawi.

4.2. Contraction of state marketing systems

Fiscal crises and increased donor leverage over policy pushed the grain marketing systems of Eastern and Southern Africa toward liberalization in the mid-1980s. After first trying to strengthen the performance of state marketing boards in the 1960s and 1970s, donors and international lending agencies began promoting the reform of food marketing and pricing as a central component of structural adjustment programs in Africa. Donors had lost patience with phased and partial reform programs that were increasingly seen as propping up costly and otherwise unsustainable pricing and marketing policies rather than facilitating reforms (Jones 1994). Political economy models (e.g., Bates 1981) further suggested that state interventions in agricultural markets, while ostensibly designed for rural development or to correct for market failures, were in fact designed to serve the interests of a dominant elite composed of bureaucrats, urban consumers, and industry.[9] The framework of policy-based lending within which market reforms have occurred in each of these countries has strongly influenced the path of reforms, and has expanded external leverage over domestic agricultural policy through aid conditionality.

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[9] Later political economy analyses also highlighted the importance of dominant rural elites (e.g. Toye 1992). These rural elites have continued to reap income transfer benefits from the structuring of agricultural policies even as state marketing programs have been contracted (Jayne et al 2002).

A major cause of the stagnation in smallholder maize production in Zimbabwe was that the costly marketing policies – for credit, inputs, and maize – could not be financially sustained from the tax base. Zimbabwe's Grain Marketing Board maize operations required government subsidies of $30-90 million annually in the mid-1980s, roughly five percent of GDP. By 1990, almost 80 percent of smallholder recipients of state credit were in arrears (Chimedza 1994). The maintenance of high maize prices to sustain surplus production also put pressure on government to cushion the impact on consumers by subsidizing the price of maize meal. Unable to tackle its mounting fiscal crisis, the Government of Zimbabwe reluctantly approached international lenders for financial support. The terms of these agreements involved a cutback in the activities that contributed to the fiscal deficit, maize marketing and credit policies being among them. As a result, Grain Marketing Board buying stations in smallholder areas were reduced. Even though 20 additional depots were established between 1985 and 1991, the number of rural collection points in smallholder areas declined from 135 in 1985 to 42 in 1989, to 9 in 1991. The real value of seasonal AFC credit disbursed to smallholders declined steadily since 1986. By 1999, the state allocated less credit to smallholders than at independence in 1980. Smallholder use of fertilizer in the 1990s has become more volatile compared to the 1980s, although it has not declined on average. Yet smallholder production has not since exceeded the levels reached in 1985 (Figure 2).

Kenya's Cereal Sector Reform Program began in 1988, and entailed a similar cutback in state grain depots. Because of the small size and dispersion of such maize sales, small traders tend to be more efficient and cost effective in handling smallholder sales than NCBP, whose activities are largely concentrated in maize-surplus, large farm areas (Karanja 1990: 34). Surveys of rural households conducted in 22 districts in 1997 and in 2000 indicate generally broad support for the liberalization process, except in the several districts where government policies traditionally have been designed to support maize prices (Jayne et al 2002). The broad rural support for maize market reform appears to be mainly driven by the majority of rural farm households who resided in maize deficit areas, who were directly hurt by the former controls that restricted direct inter-district trade in maize and therefore made them dependent on the more expensive industrial maize meal through the official marketing system to satisfy their residual grain consumption requirements (Argwings-Kodhek 1999). Lower risks and costs of maize in the post-reform period have facilitated shifts in cropping patterns to other crops that provide higher returns to land and labor. However, the reform process continues in a halting manner. The Kenyan government has several times reversed its course in the liberalization process, and has since 1999 resumed limited marketing board purchase of grain in politically important areas at fixed support prices, coupled with tariffs on maize imports. Policy uncertainty has risen in the reform period.

In Zambia, reforms did not begin in earnest until 1993 (Howard and Mungoma, 1996). Price controls were removed on all commodities with the exception of maize meal, and some restrictions on foreign exchange, imports and exports were lifted. From 1991 to 1995, interest rates rose from 50 to 120 percent over 4 months. Throughout the 1990s, the volume of fertilizer distributed on credit through government programs with very low recovery rates declined as donors withdrew their earlier support. The maize marketing board, NAMBOARD, was abolished in 1990 and replaced by a combination of private trading networks and a government organized cooperative system of crop marketing. Neither of these successor marketing networks had the ability to continue subsidizing maize production in remote areas through pan-territorial pricing. The private sector has apparently responded vigorously to liberalization in areas of reasonably well-developed infrastructure, particularly in cotton, according to surveys in districts of Central and Eastern Province (Kahkohnen and Leathers, 1999).[10] Yet for maize, the fertilizer nutrient-to-maize grain price ratios rose sharply after the decline of NAMBOARD, particularly in the areas that formerly benefited from the transport subsidies inherent in pan-territorial pricing. Farmers were caught between rising input and financial costs, lower producer prices, and a contraction of market support in remote areas. As a result, there was a discernible shift in cultivated area from maize to crops such as cassava, groundnuts, and sweet potato (in the more remote northern and northwestern areas of the country) and to cotton (in the more commercialized areas). Maize remains the main food crop in most parts of the country, but its role as a commercial cash crop has fallen sharply (Figure 3).

Despite liberalization efforts during the late 1980s in Malawi, the ex-parastatal ADMARC continued to enjoy a monopsonist/monopolist status given that Asian traders were restricted from selling in rural areas and the weak economies of neighboring countries limited cross-border trade opportunities (Christiansen and Southworth 1988), and producer-consumer price margins were often so narrow that it was not worthwhile for large traders to participate (Kandoole and Msukwa 1992). As part of the donors' structural adjustment program in the 1980s, fertilizer subsidies were gradually reduced, but when internal strife in Mozambique blocked the cheapest transport route the subsidy removal plan was abandoned. Subsidies were again removed after the change in government. In 1995, nitrogen-to-grain price ratios rose by four times their earlier levels, though the fertilizer subsidy at its highest never exceeded 20% of the fertilizer cost (Mann 1998). This occurred for several reasons: (1) subsidies were removed; (2) the devaluation of the Malawi kwacha boosted fertilizer prices disproportionately to maize prices; (3) world fertilizer prices rose; and (4) private fertilizer dealers were requiring substantial risk premiums to hold and transport fertilizer in an inflationary economy with uncertain demand (Conroy 1997; Diagne and Zeller 2001; Benson 1997). Maize prices followed export parity while fertilizer prices reflected full import costs, even though Malawi often imports maize. Since most fertilizer in Malawi is used on maize (and the remainder on tobacco), the removal of implicit subsidies in the form of over-valued exchange rates had a strong negative effect on fertilizer use. Depreciation of the real exchange rate also raised nitrogen to grain price ratios because fertilizer is imported (Minot, Kherallah and Berry, 2000; Heisey and Smale 1995). These factors, along with shifts in relative prices of competing crops, may have contributed to the moderate decline through the 1990s in the percentage of cropped area devoted to maize by small-scale farmers (Figure 4).

None of the African governments in this study were able to find an internal solution to the large deficits to which their agricultural policies in the 1970s and 1980s contributed. Nor would external donors agree to make loans without redressing the sources of states' treasury deficits. Fiscal crises were the driving force behind the acceptance of structural adjustment. Yet an analysis of the implementation of maize marketing reform over the 1990s concludes that many states have actually pursued a *de facto* continuation of former control policies, albeit in a more contracted way that has left out most smallholder farmers while continuing to provide benefits to politically important farming interests (Jayne et al., 2002). In each of the four case study countries, the main state maize marketing agency continues to exist, sometimes in a reconstituted form, and remains a major player in the market. This contrasts markedly with

[10] Since liberalization, the mill-to-retail maize marketing margins within cities has declined, though farm-to-wholesaler marketing margins between cities has increased. Some of the main causes of higher margins were inadequate transportation infrastructure high transaction costs caused by weak contract enforcement, impacted information, and policy uncertainty caused by continued government distribution programs especially in more recent years (Kahkohnen and Leathers 1999: 21; Govereh et al 2002).

cereal market reforms elsewhere in Africa where state grain marketing agencies are now largely defunct (World Bank 1994).

Moreover, there have been few initiatives to support private trading activity and to develop the public institutions required for a privatized marketing system to function effectively (Jayne and Jones 1997; Kherallah et al., 2002). To some extent, the removal of government controls on grain trading appears to have mitigated the adverse effects of declining state marketing subsidies associated with structural adjustment. Lower grain processing costs made possible through liberalization have reduced the wedge in some countries between producer prices and consumer prices (Rubey 1995; Jayne and Argwing-Kodhek 1997). In some cases, price spreads between surplus and deficit regions have declined (Nyoro et al 1999). Evidence indicates that the number of private traders serving smallholders has increased, especially in high-potential areas, within several years after the initiation of partial food market reform (Amani and Maro 1992; Kaluwa 1992; Nyoro et al 1999). However, in contrast to other regions in Africa where liberalization helped to dismantle agricultural taxation, the transition from controlled to market-oriented systems in Eastern and Southern Africa has reduced state expenditures on agricultural marketing investments and subsidies. In Zambia, for example, maize and fertilizer subsidies, in constant 1998 kwacha, declined from an average of 250 million kwacha per year in the mid to late 1980s to under 50 million kwacha per year since 1993.

4.3. Maize seed industry

The genetic advances needed to sustain or enhance maize yields depend on past investments in maize research, with lagged effects. In Kenya, public maize research expenditure declined in real terms from 1980 through 1990. USAID withdrew its technical assistance in 1977, but in 1987, the government asked it to resume support. The scientific and institutional cooperation that created the maize success story of the 1960s and 1970s collapsed in the 1980s, as a combination of fiscal crises and donor pressure weakened public financial support for research, extension, and credit (Hassan and Karanja 1997). In Zimbabwe, Eicher (1995) warned of declining government commitment to maintaining the continuity of research funding and scientific leadership, based on a declining real budget for agricultural research from 1987. Public sector funding of agricultural research declined by 39% in real terms between the periods 1975-1985 and 1990-2000.

Karanja has contended that the yield potential of successive maize seed releases in Kenya continued to rise but the rate of increase declined (Karanja 1990). In plant breeding, yield breakthroughs of the type obtained when Kitale Synthetic II was crossed with Ecuador 573 are periodic rather than routine; "the yield advantages offered by early releases were the cream to be skimmed off the milk"(Harrison, cited in Gilbert et al. 1992:29). In all case study countries, a more disturbing problem is that smallholders are likely to be even farther from realizing yield potential, for reasons not confined to weather. One reason is that the genetic advances offered by breeding research have not been matched by agronomic practices and efficient support services for smallholders, many of whom are located in marginal areas (J. Ransom, pers. comm.2002; Hassan et al. 1998; Rusike and Eicher 1997). As adoption of improved maize moves into more marginal areas the effects on national yield levels are also numerically marginal (Byerlee and Heisey 1996). Simply put, "there is little to no advantage of using a hybrid if the yield potential of your soil is less than 1 ton"(J. Ransom, pers. comm.). The secular decline in soil fertility in the intensive maize systems of this region has been aggravated by slackened fertilizer use and the abandonment of traditional methods of soil regeneration as populations rise (Lynam and Hassan 1998). With the removal of subsidies, high nutrient-grain price ratios, linked to high transportation costs, have eroded the profitability of fertilizer use (Morris, Tripp, and Dankyi, 1999; Heisey and Mwangi; Minot, Kherallah and Berry, 2000). In addition, pest and disease problems have worsened with intensification. Advances in yield maintenance rather than yield potential may hold the greatest promise for this region (Lynam and Hassan 1998; De Vries and Toenniessen 2001), though costs of resistance breeding are relatively high, and yield "savings" from this type of breeding are not always perceptible to farmers.

At the farm level, seed supply problems have accompanied the patchy, incomplete process of seed market liberalization. On one hand, it is reasonable to ask why public sector companies in eastern and southern Africa persist in emphasizing hybrid maize, which could be provided as well or better by private companies (Tripp 2001). On the other hand, growth in seed sales in Kenya slackened considerably in the 1980s and has recently declined (Karanja 1996; de Groote, pers. comm. 2002), apparently provoked by inefficiencies and seed quality problems. More recent publicly-bred releases have diffused more slowly than did their predecessors (Karanja 1990; Hassan et al. 1998; Bourdillon et al. 2002). In Zimbabwe, a number of private companies compete in the seed market, but the government maintains a firm grip on variety release and seed importation, which can be counterproductive (M.Banziger, pers. comm., and Tripp (2001). Seed Co-op has remained an important actor due to its research capacity, a diversified asset base, and collaborative technical agreements with a range of multinational companies (Rusike 1998). Though private investment may be compensating for declining public research budget and there is no apparent slowdown in the rate of variety release, companies do not target the specific needs of marginal areas in Zimbabwe, such as IOPVs and stress tolerance (M. Banziger, pers. comm.).

Liberalizing the market in Malawi only exposed its deficiencies, especially in the maize-surplus producing areas of the North, where population densities are low. Since the most common hybrids in Malawi yielded more than local maize without fertilizer at the seed prices that prevailed through the early 1990s, it made economic sense for farmers to grow hybrids even if they could not apply fertilizer (Heisey and Smale 1995; Benson 1999). However, the seed-to-grain price ratio nearly tripled between 1989 and 1997, and even if farmers could access the cash to purchase a hectare of hybrid maize, it is unlikely that smallholders in many environments would have enjoyed the yield advantage required to pay the seed costs (Benson 1999). Furthermore, official price ratios in no way incorporated the transactions difficulties experienced by smallholders. Though a number of key steps were taken, in a 1995 report on the retail trade in agricultural inputs, Tsoka concluded that policy, legislative, and regulatory frameworks were not conducive for retailers' participation in the marketing of agricultural inputs. In 1997 as compared to 1990, farmers purchased their seed from a range of retail sources, though ADMARC remained the major source of seed (Smale and Phiri 1998). In 1998, Monsanto bought the controlling share of NSCM. Recent studies in the Central Region suggest that while the use of agents in maize seed distribution has extended coverage, smallholders pay almost 20 percent more in retail outlets than at the depot (Nakhumwa, 2002). Although there are several companies operating in Malawi, much of the Monsanto-Malawi seed sales have been marketed through the supplementary inputs programs (see Box 3), as Cargill-Malawi's were previously channeled through the smallholder credit system. All company representatives interviewed by Nakhumwa (2002) reported that seed sales are constrained by the low disposable income of farmers, a unpredictable growing environment, and a stagnating market.

4.4. Crisis-motivated Maize Policies

Malawi provides an illustrative example of the erratic policies of the 1990s that have directly affected the maize germplasm supplied to smallholders, and consequently, yields (Box 3, Figure 5). Disruptive policy initiatives, sometimes pushed by donors, appear to have exacerbated the deepening poverty that has resulted from failure to redress the long-term structural problems in the economy (Kydd and Christiansen 1982; Lele 1990; Sahn and Arulpragrasam 1991) and those factors more specific to the 1990s, described above.

In June of 1993, Malawians voted to change their government to a multiparty system from an oppressive, single-party dictatorship. Following this historic decision, many other changes occurred in the organization and delivery of inputs. While it became obvious that the promise of seed technical change in maize production would require addressing long-term structural factors —investing in physical infrastructure to reduce transfer costs, strengthening institutions to mobilize rural financial systems, continued investments in agricultural research and extension, and a stable agricultural policy environment—much of the cumulative learning from years of maize research in Malawi appears to have been discarded in favor of short-term, crisis-motivated solutions. Initiated during a food crisis in 1996-7, though originally conceived as a technology-based plan that was cheaper than importing maize, the Starter Pack (SP) and Technology Input Program (TIP) have functioned as a relief effort, since the research input into the package they extend is minimal. In effect, a farm input subsidy system with controlled maize prices seems to have been substituted by in-kind transfers with full price liberalization, though the social welfare implications of the switch are unclear (Levy et al. 2000; Levy and Barahona 2001; Sibale et al. 2001; Box 3). Similar crisis-motivated approaches have substituted for long-term investments in public goods both Zimbabwe and Zambia (Rohrbach et al 2002).

V. OUTCOMES

5.1. Cumulative adoption

Cumulative adoption rates for modern maize types are high in Kenya and Zimbabwe, and remain relatively high in Zambia [65%-100%], relative to Malawi where adoption stands at roughly half that level (43%)] (Table 2). Ranges in the data shown for 1996 reflect differences between national program and seed sales estimates. As a result of continued infusion of these materials through farmer purchases and seed distribution schemes, and of the involuntary mixture of germplasm types through cross-pollination in farmers' fields, it is difficult to estimate reliably the areas under improved seed.

5.2. National maize productivity

During the episodes of success as we have defined them, growth rates in maize yields were positive in all case study countries and a sizeable component of the positive growth in maize production was attributable to yield (Table 3). Growth rates in maize yield and production were negative in the 1990s in each country except Malawi, where a few years of favorable weather and continued infusions of improved maize seed and fertilizer through free input distributions seems to have had an impact[11]. Malawi's successful period, relatively brief and delayed, overlaps the 1990s. However, estimated growth rates mean little when coefficients of variation are so high. Maize yields are most variable in Zimbabwe and considerably more stable in Kenya than in any of the other countries. Furthermore, changes in actual aggregate maize yields underestimate the true achievements in maintaining yields against a naturally deteriorating germplasm and soil resource base (Gilbert et al. 1993). In none of the case study countries has actual maize production per capita kept pace with population over the past 40 years (FAOStat). Even so, seed technical change clearly promoted these countries' ability to feed themselves at a lower cost to consumers than otherwise would have been the case.

5.3. Farmer income

Net farm income from using maize hybrids and fertilizer depended not only on stable, controlled input/output ratios (particularly the nitrogen to grain price ratio), but also on direct and hidden subsidies that reduced that transactions costs faced by smallholders. The illustrative partial budgets shown in Table 4 suggest that the returns to land in maize cultivation declined dramatically between the episode of success and the subsequent period, considering the costs of credit, seed and fertilizer after the collapse of the smallholder credit scheme, subsidy removal, and devaluation. After subsidies on seed, fertilizer, and especially those on credit were removed, and in a year that real nitrogen and seed prices reached their zenith relative to the real output price, returns to land and labor were in the negative range for fertilized hybrids, and incentives

[11] In Malawi, advanced-generation hybrid seed is likely to have gradually replaced local maize and F1 hybrid seed. Survey estimates suggest that in the major maize-producing zones between 1990 and 1997, local maize as a percent of total estimated maize area declined from 85 to 60 percent, while the percent planted to F1 seed was similar (12 and 10, respectively). From 1990 to 1997, however, only a scant 7% of farmers were able to grow F1 seed in each season (Smale and Phiri 1998). The estimated area in recycled hybrid seed rose from 2 to 30 percent, however, with IOPVs still representing only 1 percent. This pattern is likely to have become generalized for the nation from 1998 to 2001 with the subsequent annual infusions of small quantities of hybrid seed with Starter Pack and TIP schemes.

shifted toward the cultivation of unfertilized local maize. For many smallholders, these figures in no way capture the sheer physical difficulty of obtaining the inputs when the marketing system changed.

Static, partial budgets reveal only a snapshot in time, however. Smale et al. (1991), Heisey and Smale (1995), Benson (1997), and Diagne and Zeller (2001) reported partial budgets and probability distributions of net returns constructed over a period of a decade in Malawi, with large numbers of yield observations from farmer surveys, on-farm trials and demonstrations. The relative profitability of fertilized and unfertilized hybrid seed relative to the local benchmark varied by the growing season, whether or not subsidies were in effect, and whether the household was a net buyer or consumer of maize. Detailed analysis of more then 1,900 trials conducted nationwide in 1995-6 demonstrated that in that season, the most profitable recommendation for farmers in most areas of Malawi was to apply *no* fertilizer at all; fertilizer use at any level only made economic sense when maize was produced for home consumption (because of wide price bands) *and* the household had other cash-earning activities to finance its purchase (Benson 1997). Practically speaking, because maize is a food crop, smallholder credit has not been available for use in purchasing maize seed and fertilizer since the mid-1990s. In Malawi at least, instability in input-output price ratios seems also to have wreaked havoc with smallholder farm incomes.

5.4. Equity

On one hand, detailed adoption studies in case study countries demonstrated that during the episodes of success, maize hybrids and fertilizer were adopted by some of the poorest, smallest maize producers in the world -- turning on its head the stereotype of the commercial hybrid grower (Gerhart 1975; Howard 1994; Smale 1992; Hassan et al. 1998). For example, in the major maize-producing regions of Malawi in 1990, an estimated 36 percent of farmers with an average farm size of 1.2 ha planted F1 maize hybrids. As is commonly demonstrated in microeconomic models of adoption, the likelihood of using hybrid seed differed by household assets such as total landholding, human capital variables such as farming experience and past extension contact, and physical factors such as the agroecological zone. Access to extension and credit linked to input use and output markets, often through club membership, was a major explanatory factor. Access to oxen was significant in areas where farmers used animal traction, such as Zimbabwe and large parts of Zambia (less so in Kenya and Malawi).

In their 1995-1996 survey of 400 households in five districts of Malawi where microcredit schemes operated after the collapse of the smallholder credit program, Diagne and Zeller (2001) found that when households chose to borrow they realized lower net crop incomes than non-borrowers—for several reasons—though most they related to growing hybrid maize with high rates of fertilizer application. The finding of the greater downside risk (higher cumulative probabilities of lower net margins in the negative range) of fertilized hybrid maize is consistent with some of those reported earlier for major maize-producing areas (Smale et al. 1991).

By 1991-92, 60 percent of the total small/medium maize area was planted to Zambian improved maize types (Howard 1994), with adoption rates differing by agroecological zone. Adopters were, as expected, those with larger farm sizes, larger household sizes (labor stocks), and those who used animals or machinery rather than hoes. They had more formal education and had been visited by extension agents. The majority lived close to service centers or roads, received credit for maize and sold maize output, and were dependent on local rather than regional depots.

In Zimbabwe, as in the case of Kenya, the largest gains in smallholder maize production and sales were concentrated among farmers in areas with better rainfall and those owning more land and livestock. Based on detailed Grain Marketing Board data on maize purchases from 1985-1991, Jayne and Rukuni (1993) report that 10% of the smallholder farmers accounted for 90% of the maize sold during this period to the Grain Marketing Board by smallholder farmers. Recent analysis using nationally-representative survey data in Zambia (Tembo et al, forthcoming) has shown that in 1999/2000, 10 percent of farmers defined as small and medium scale (under 25 hectare farms) accounted for 78 percent and 93 percent of the maize produced and marketed, respectively, by these sectors. Jayne et al (2002) found similar results in Kenya. The main attributes distinguishing these farmers is (a) location in "high-potential" areas with long growing seasons suited to the long-maturing hybrid maize varieties released in the 1970s; (b) relatively large farms by smallholder standards (in the over-five hectare range).

In Malawi, the greatest problem affecting the use of improved maize seed and fertilizer since 1993 has not been the input-output ratio or the profitability of the technology (since most farmers are net consumers) but cash flow and the continued erosion in the effective purchasing power of rural households with successive devaluations, inflation and other macroeconomic changes. Until the purchasing power of the 60 percent of households in Malawi that are maize-deficit is raised, "higher maize prices translate into increased misery" (Benson 1997:20). Based on her longitudinal research in the Shire Highlands of southern Malawi, Peters (1996) argued that market liberalization provided new opportunities (through tobacco and maize sales) that have disproportionately benefited the better-off households, while the poorest 25% experienced a relative worsening in income and food security. By retaining more maize, selling more labor, and increasing the budget share of purchased maize, the poorest quartile of the households suffered a decline in food security.

Changes in the marketing system had shifted the spatial locus of hybrid maize production, given the relative land-abundance and lower road density of the the Northern Region. Between 1990 and 1997, the percent of farmers growing F1 hybrid seed dropped from 40% to 18% in the villages of the Northern Region, where farmers had previously produced a surplus and grown the crop for cash (Smale and Phiri 1998). Although the farmers in the villages of Blantyre District, Southern Region were using F1 seed, they farmed such small areas and used such small amounts that they could not market a surplus. The farmers most consistently growing hybrid maize over the intervening years from 1990 to 1997 period were found in the villages of Kasungu District in Central Region, where tobacco and other cash crop opportunities were consistently better.

In Zambia, following price liberalization, "nearly full regional and seasonal differentiation of maize and other crop prices occurred" to reflect market conditions and transactions costs (Howard and Mungoma 1996). National maize area contracted relative to the expansion of the 1980s, particularly in the drier and more remote regions. Crop mixes have diversified according to agroecological endowments and distances from transport infrastructure. Exports have doubled in value and become more diversified, including sugar, cut flowers and specialty crops. On the other hand, many farmers are now "left out" of market processes.

5.5. Consumption

There were undoubtedly widespread benefits to consumers during this maize production "boom" period, in Kenya, Zambia and Zimbabwe. Rapid rates of population growth would have resulted in a costly import bill had there been no maize production expansion during this period —which would have added to the nation's external debt (Gilbert et al. 1993: 34). However, the controlled marketing systems during the boom period did not always allow the decline in real producer prices during the late 1980s to translate into lower consumer prices (Jayne and Jones 1997). In fact, real prices of packaged maize meal during the late 1980s in Zimbabwe remained relatively constant, despite falling real producer prices, as industrial millers benefited from their regulated oligopoly position in the official marketing system (Jayne et al 1995). Moreover, detailed farm-level studies in Zambia and Malawi were unable to demonstrate a link between adoption of hybrid maize and improved nutritional status of household members (e.g., Siandwazi, Bhattarai, and Kumar 1991; Diagne and Zeller, 2001).

5.6. Fiscal sustainability

In Zimbabwe, Kenya, and Malawi, published analyses suggested that public investment in maize research paid off (ranging from 43 to 64 percent, depending on assumptions and time periods), even when curtailed by a small market, as in Malawi (Kupfuma, 1994; Karanja 1996; Smale and Heisey 1994). However, these findings overestimate returns since they do not account for the allied investment costs in market infrastructure, credit and input distribution programs, and pan-territorial pricing policies that encouraged the uptake of this technology. Costs were indeed high. Both the National Cereal and Produce Board (NCPB) in Kenya, and the Grain Marketing Board in Zimbabwe incurred losses equivalent to five percent of their countries' GDP during parts of the 1980s (Jayne and Jones 1997). Zambia's input and output marketing subsidies were equivalent to 17 percent of the total government budget in the late 1980s (Howard and Mungoma 1996).

Only Howard's (1994) analysis for Zambia explicitly includes the costs of a full range of investments leading to hybrid maize adoption by smallholder farmers. Marketing costs accounted for roughly 59% of the total costs of all investments, in contrast to the seed research investments, which were only 3% of the total. Extension and other service provision programs accounted for the remaining 38%. The rate of return on maize research was highly favorable when the costs of marketing were not included. Yet after including all investments (research, extension, seed and marketing), the average rate of return to maize research in Zambia was negative over the 1987-91 period.

VI. SUMMARY

We have argued that from 1900 to 1965, 1) the agronomic suitability of the crop, 2) the British starch market, 3) milling technology, 4) the integration of Africans into the settler economy and 5) market and trade policies established through agricultural settler lobbies explain to a large extent why white maize became the dominant food staple in the case study countries and the preferred staple of today's African consumers. Furthermore, many of the institutions established during the colonial period, as well as colonial investments, generated benefits for smallholder maize production in the post-independence period. They spurred the maize breeding successes in Kenya and Zimbabwe before 1965. Of the two, however, only Kenya's was a smallholder maize revolution. Zimbabwe's brief smallholder maize revolution followed about twenty years later.

In our case study countries, we conclude that the maize "seeds" produced—that is, the quality of plant breeding and agronomic research that accompanied it—were an unquestionable success. In retrospect, the "maize success stories" were largely a phenomenon of the 1970s and 1980s. During the 1990s, all four countries experienced absolute declines in maize production, with the exception of Malawi, where production was supported through free input distribution programs. This underscores the obvious conclusion, also stated by Byerlee and Eicher (1997: 251) that seed genetic change is a necessary but not a sufficient condition for improving the welfare of African smallholders. In the last decade since the data assembled in their work were compiled, the necessary investments in germplasm have further declined while the investments in the institutions required to translate germplasm advances into improved income, including seed and grain markets, have faltered. The public investments in state-controlled, coordinated input and output markets were not fiscally sustainable and generated social costs by directing more resources to maize production and improved maize in areas where farmers may not have chosen to grow it otherwise. The dismantling of the systems that supported these episodes of success generated an uncertain decision-making environment for farmers who were already beset by unfavorable weather conditions. Estimating the true counterfactual, or the social costs of not having pursued either the research or supporting investments would require not only a general equilibrium framework, but knowledge of yield levels in the absence of improved germplasm and the partial effects of genetic as compared to all other intervening physical, economic and social factors.

Maize successes in the future will continue to depend on strategic crop improvements such as those targeted to relieve specific environmental and disease problems and enhance the stability of net returns to farmers, but also on enabling these advances to release land for alternative uses and diversify the income sources for farmers, regions, and nations. The continued development of seed markets and a realistic understanding of the farmers who are the actors in those markets remain critical. Two maize breeders in two time periods, M.N. Harrison in 1970 and D. Duvick in 2002, have already delivered these messages.

A third, vital point concerns whether states will make the investments needed to support more efficient private systems of input delivery, finance, and commodity marketing, not only for maize but for a range of crops that may offer higher returns to farming in the changing environment of Africa's rural areas. Because most parts of Africa are experiencing increased land pressure and limited potential for area expansion, population growth is causing a decline in land/labor ratios and farm sizes are declining. According to national surveys, about 50 percent of the small-scale agricultural households in Zambia, Mozambique, Kenya, Rwanda, and Malawi own less than 1.5 hectares of land (Jayne et al 2002). Maize is a relatively low value-to-bulk crop. It can provide consistently high returns per unit of land in only a relatively small proportion of smallholder farming areas in the region. Given reasonable assumptions about future productivity improvements, it is unlikely that maize can provide the net revenue on the millions of farms that are 0.5-1.0 hectares or smaller to generate substantial crop income growth, especially in the semi-arid areas. Overcoming rural poverty will require achieving much higher returns on small farm sizes. This will require the same type of sustained support of institutional, policy, and technology systems for a wide range of other crops (e.g., sugar in the lowlands of western Kenya, tea in the highlands, cotton in semi-arid parts of Zimbabwe, Zambia, and Kenya, and horticulture where water control is possible and where transport infrastructure to export markets can be developed. Allied investments in education and skill development, market infrastructure, and agricultural research programs for a more diversified set of crops will all be critical.

However, even if successes are achieved in moving toward higher-return cropping patterns, maize will remain a crucial part of the food security equation in two ways: first, as a purchased commodity for satisfying the food requirements of a more diversified rural economy, and second, as a cash crop in areas where it is agro-ecologically suited to provide high returns (e.g., Kenya's North Rift, Zimbabwe's Mashonaland maize belt, parts of Zambia's Central and Southern Provinces). Overall however, rising land constraints will progressively encourage farmers to shift toward crops providing high returns to scarce land – provided that the marketing and institutional infrastructure allows them to do so. This will be manifested in a shift from the strategy food self-sufficiency strategy to a comparative advantage strategy.

While such a shift will be crucial for poverty alleviation for millions of small farms in these countries, particular in semi-arid areas, this outcome is not assured. Governments have an important role to play in building the institutions to reduce the transaction costs and physical costs of trade, supporting agricultural research and development, education and extension, and investing in the development of reliable and low-cost food, finance, and input marketing systems to serve rural areas, so that households can benefit from the higher incomes afforded by a well-functioning commercialized agricultural sector while still ensuring their access to food (Dorward, Kydd, and Poulton, 1998).

Lastly, can a local constituency be formed to successfully stake a claim on public resources over the long run to support agricultural research, marketing institutions, and other kinds of growth-promoting public goods? These issues underscore the strong connection between agricultural development and governance. The early success of the maize industry in Zimbabwe and Kenya can be largely attributed to the strength of the institutions built by settler farmers, which provided a constituency to encourage sustained public and private support for the sector. Today, farm lobbies are generally weaker, more fragmented, and reflective mainly of large-scale farmer interests. Representation has always been weak for smallholder farmers, particularly in semi-arid regions where their welfare is closely tied to the reliability and efficiency of maize markets where they purchase maize as consumers. A crucial issue is how the key growth- and equity-promoting investments in agricultural research, infrastructure, and market institutions can be financed. Perhaps most importantly, where will the domestic political pressure for these public investments come from?

Box 1. Cross-cutting themes: Episodes of success in Ghana, Nigeria, and Ethiopia

The cases of maize in Ghana and Nigeria are distinct from those of Eastern and Southern Africa in important ways. First, until recently, the germplasm focus has been different, emphasizing open-pollinated varieties instead of hybrids. About 75% of all improved maize types released in West Africa as a whole from 1965 were open-pollinated synthetics and composites rather than the hybrids that have dominated in ESA (Manyong et al. 2001). Second, and more importantly, the role of maize in the food economy means that while it is less important as a source of food, it is extensively traded and has been attractive to farmers as commercial crop. In neither case was the political economy of the country oriented toward the production of maize as a wage good.

Maize falls far behind roots and tubers as a source of calories in Ghana, but farmers identify it as an important source of cash income (Morris, Tripp and Dankyi 1998). At least half of Ghana's maize production enters markets, which have long been controlled by the private rather than the public sector (Tripp and Marfo 1997). Recent evidence suggests that seed markets do not appear to function as well as the grain market, however. Farmers rely to a large extent on other farmers for seed information and often cannot name the variety they grow (Morris, Tripp, and Dankyi 1999). Since the beginning of the national maize breeding program in Ghana (Ghana Grains Development Program) in 1979, most releases have been improved open-pollinated varieties, though several quality-protein maize (QPM) hybrids were released from 1997. The emphasis on OPVs reflected the fact that, to maintain the yield advantages of hybrids farmers must purchase fresh seed every cropping season and are therefore dependent on a seed industry. However, farmers who grow IOPVs are also advised to replace their seed after several seasons, and seed quality must in any case be assured. After the collapse of the parastatal Ghana Seed Company, the NGO Sasakawa-Global 2000 was instrumental in establishing a system for the production and marketing of OPV maize and cowpea seed, which Tripp (2001) concluded has been one of the more viable examples of project-initiated small-scale seed production to be found in Africa.

Based on farmers' qualitative judgments, Morris, Tripp, and Dankyi (1999) found that the adoption of improved maize types has been associated with significant farm-level yield increases and noticeable increases in farm income earned from maize sales. They estimated high benefit-cost ratios, and the tradability of the crop in Ghana as well as farmers' responses indicate that these benefits might actually have been earned. As elsewhere, however, they found that the adoption of improved seed and fertilizer is affected indirectly by factors beyond the control of researchers—including agricultural extension service, the inputs distribution system, and the policy environment. With the privatization of fertilizer imports and distribution, combined with the elimination of the fertilizer subsidy during the 1980s and 1990s, the nitrogen-to-maize price ratio rose exponentially and uptake fell.

Nigeria inherited the strongest research system in West Africa at the time of independence (Gilbert et al. 1993: 54), and TZB, the first highly successful IOPV, was bred during the 1960s. Maize expansion was initially driven by its potential as a source of cash through sales to established southern markets—the taste for maize developed only gradually as it was mixed into *tuwo*, marginally improving protein content, and was used for feed or brewing beer (Gilbert et al. 1993: 61). While maize had been a minor crop through the mid-1970s, it displaced cotton and groundnut as a cash crop and sorghum and millet as a food crop in the 1980s, making the Northern Guinea Savannah one of the most intensified areas in West Africa. Significant determinants of this change were exogenous to farmers' decisions: (a) an improved transport system; (b) the release of and improved maize variety (TZB) that was well adapted to an ecology that was naturally suited for growing maize because of high solar radiation and low night temperatures, and had a high grain yield response to modern rates of nitrogen application; (c) high levels of fertilizer subsidy (dating back to the 1950s), though fertilizer was not widely used until the adoption of improved maize (Smith et al. 1994). At that time the net margin per hectare of improved maize was six times the net margin for the traditional food crop mixture of sorghum and millet, and maize was seven times as profitable as the traditional cash crop, cotton (Balcet and Candler 1981). A budget from Norman, Simmonds and Hays (1982) showed that the returns to labor for maize in the early 1980s were superior to other crops in the system (Table 5). Survey results indicated that cash earnings from maize were a primary source of agricultural inputs for use on other crops, substitute for underdeveloped credit markets and generating income multipliers (Smith et al. 1994).

Several years after the first study, Smith et al. (1997) recognized that yield advantages came at a fiscal cost. The fertilizer subsidy was around 85% of the real cost of delivering fertilizers to farmers, and the fiscal cost of the subsidy was 32% of federal government agricultural expenditure and 3.7% of total government expenditure. Oil revenues enabled the suppression of the nitrogen-to-maize price ratio to levels as low as 0.9-1.9 from the mid-70s through the 1970s and 1980s. Fertilizer subsidies led to "fiscal problems, inefficiencies, corruption, and unsustainable predominance of cereal cropping…."(Smith et al., 1997: 123). They concluded that although high-yielding, fertilizer responsive maize can make a major contribution to food production in Nigeria and other areas in Africa, it can do so only in a limited number of areas. "Production systems in Western Africa, even intensive ones, require diversity to be sustainable" (Smith et al., p. 124, 1997) since they are inherently complex and heterogeneous.

The recent Ethiopian experience demonstrates the pitfalls of successfully pursuing a production-oriented strategy without sufficient concern for market-related factors. The government extension services did such a good job of scaling up their half-hectare extension plots during the late 1990s (reaching 5 million farmers in 2000) that farmers produced bumper harvests in the high potential zones. Insufficient local demand for maize, combined with the simultaneous sales of large harvests by many farmers in order to meet financial and social obligations, led to plummeting prices and had serious repercussions on farmer welfare. In the subsequent season, fertilizer use declined and famers reverted to local maize or planted second-generation hybrid seed (D. Tanner, pers. comm., and Lemessa, 2001).

Box 2. Farmers' perceptions

At the outset of the 1991/92 season, the Malawi Ministry of Agriculture, CIMMYT, and National Seed Company of Malawi undertook a farmer evaluation survey in which 150 farmers in clusters of villages located in Central Mzimba, Kasungu and Blantyre Districts compared the yield, maturity, processing and storage quality of newly released semi-flint hybrids MH17 and MH18 to those of their own local maize and the previously released, dent hybrids MH12 and NSCM41. Each participating farmer was provided with a 5-kg sample of two hybrids and asked to grow them with usual practices. Enumerators laid yield sub-plots to measure their yields and interviewed them later in the season regarding their perceptions.

In the drought year that followed, farmers harvested highest yields with MH18, even when they applied no fertilizer to either the hybrid or their own local check. Their statements conveyed their surprise about the new hybrids. MH18 was often called "the local seed you gave us," as compared to the "real" dent hybrids, NSCM41 and MH12. One farmer said "you have given us back the local maize we used to grow." Because flint type and pounding efficiency were long associated with local maize, farmers called seed that satisfied those conditions "local." Others insisted that the semi-flint hybrids were local maize and that they would keep the seed (Smale et al. 1993).

Several of the participating farmers later traveled to Lilongwe to discuss their experience on the radio with Ministry of Agriculture field staff, B.T. Zambezi, who bred the hybrids, and representatives from NSCM, who sold them. Alesi Matope, from Chiradzulu in Blantyre District, reported "I have been farming for a long time and I used to plant local maize and NSCM41. In 1989, the field technicians brought MH17 and MH18, which I planted. Although there was little rainfall, I had good yields compared to local maize and the hybrid matured earlier. When I harvested this maize, the advisor came and told me that I should store a little of each because a visitor would come from Lilongwe to see me, and to see the yield, storage and poundability of these hybrids, and to see which seed produced more bran. I did not apply any chemical to prevent weevils. NSCM41 was the first to be attacked by weevils. When pounded, MH17, MH18 and local maize produced little bran. The *nsima* made from this type of hybrid is very tasty and its colour is pure white. The roasted green maize is even better, and of course when shelling from the cob, it shells very easily and one does not have to struggle with the task." Jaleki Kapinga from Kasungu reported that "when setting off on my visit to Lilongwe I was told to tell the truth about the MH17 and MH18 hybrid seed by all other farmers in my area. 'They should breed plenty of seed.' That is what my fellow farmers told me to tell you…We do not want to find problems in buy MH17 and MH18 hybrid seed in our markets." Lyson Mbewe from Central Mzimba said that his wife insisted on keeping the seed from the harvest, even though he told her it was only an introduction. This photo of Mayi Jumbe, another farmer from Thyolo in Blantyre District, seated on the top of her maize harvest after the drought year, was later displayed on one of the annual reports of the Maize Commodity Team.

Box 3. Crisis-motivated maize policy in Malawi

During the worst drought year of 1991/92, an amnesty was granted to on smallholder loans. Credit expansion in 1992/93 brought in new, less credit-worthy borrowers, and loan repayment problems were aggravated by the election year promises of politicians to forgive loans. Massive defaulting on smallholder loans and a liquidity crisis ensued in 1994, leading to the collapse of the smallholder credit scheme.

From April 1995, in recognition of the need to diversify crop production, prices of all inputs and crops *except maize* were fully liberalized and the extension service began promoting other cross and activities, including cassava and sweet potatoes, and grain legumes to serve in crop rotations and better nutrition. In maize, the government implemented a price ban system to dampen extreme variation in maize availability and prices. The difference between import and export parity prices is great in Malawi, however, and the band therefore had to be narrower to cushion both consumers and producers from risk of destabilizing price swings (Mann 1998).

In the 1996-7 season, grain reserves were insufficient to release into the market, and government, which retained regulatory control over imports, imported maize too late (as also occurred in 2001). Private traders extracted rents by buying rationed maize and selling it at even higher prices outside ADMARC gates. Ironically, liberalization was blamed for the shortages and high prices, although these effects arguably were more attributable to continued regulatory barriers blocking private importation of maize. Government's attempts to defend ceiling prices without importing the supplies necessary to do so only exacerbated the perception of exploitation by private traders. There were reports of maize theft of green maize from fields and lynch mobs despite security measures, and widespread disillusionment from liberalization. Emergency imports were costly and high maize prices created inflationary pressures (Mann 1998). Until the purchasing power of the 60 percent of households in Malawi that are maize-deficit is raised, "higher maize prices translate into increased misery" (Benson 1997:20).

In response to a crisis situation, the Starter Pack Initiative was proposed. The rationale for the Starter Pack schemes that were first implemented in 1998/99 was to use the "best bet" technology (based on the area- and objective-specific fertilizer recommendations of the Maize Productivity Task Force) to "jump-start" maize production for all smallholders. As originally conceptualized, then, the program built on the technical knowledge of the maize research program to refine a package distribution system that was cheaper and more effective in relieving the food security problem than costly food imports in a dysfunctional maize marketing system. The plan was to differentiate starter packs from a free inputs program, containing no more than enough seed and fertilizer for 0.1 ha, and in addition to hybrid maize seed, seed of other crops, with "well formulated and presented educational materials." The program was perceived as a long-term development program (5-10 years) rather than a quick fix—and by early calculations, paying for itself in terms of both incremental maize output and other benefits from rotations and intercrops. Since F2 seed of Malawi's hybrids still yield more than local maize, benefits would even accrue from farm-saved seed of each year's allotment. This approach was considered more effective than input price subsidies, reaching the poorest rural households more effectively than would credit programs. Starter Packs with hybrid maize and other seed were distributed to nearly all Malawian smallholders (3.5 million) in the 1988-99 and 1999-2000 growing seasons, and in the 2000-01 growing seasons, the scheme was replaced by the Targeted Inputs Programme, designed to deliver IOPV maize and other seed to 1.5 million of the poorest smallholders.

Practical considerations of the SPI and TIP schemes proved to be different than its original conceptualization—at least with respect to germplasm. Though the daunting task of distributing inputs was accomplished, the logistic challenges seem to have precluded any precise targeting of the maize varieties. The amount of maize seed distributed in the first year (1998-99) was about 150% of the country's certified seed production in the previous year)—leaving many packages filled with grain from ADMARC stocks rather than seed. Since some of the hybrid maize seed was sourced from South Africa, Zambia and Zimbabwe (likely dent) due to insufficient supplies of MH18, MH17 and NSCM41, it is likely that much of it did not perform well. The scheme disturbed the distribution of recommended varieties by sending them to the wrong destinations (Longley, Coulter, and Thompson 1999: 105). Not surprisingly, the incremental maize yields attained were fairly low. Furthermore, though there is quite a range of hybrids offered by the three major competitors in Malawi—on paper, at least (Ngwira, Kabambwe and Nhlane, 2002)—sales have been thwarted by seed provision schemes (Nakhumwa 2002).

When harvests were exceptionally good in several seasons, donors apparently turned coat and began to complain about the welfare nature of the SP scheme (Nation, August 16, 2000). The 2000-01 program, called the Targeted Inputs Programme, provided for roughly half the number of beneficiaries (1.5 million) as the previous two schemes, and distributed 0.1-packs of fertilizer, IOPV maize seed through a voucher system targeting the poorest half of the smallholder population as part of Malawi's National Safety Net Strategy (NSNS). Both of these aspects—the scaling down and move towards "more sustainable inputs" were seen as part of an "exit strategy" from Starter Pack.

The TIP scheme no longer aimed to promote the use of hybrid maize, on the grounds that IOPV seed was thought to be more "sustainable." The justification for this perception is difficult to find, for at least one of several reasons. First, in the past, yield advantages had been quite low with existing Malawi IPOVs, though Masika and some recent introductions through CIMMYT-Zimbabwe appear promising (Ngwira, Kabambe and Nhlane 2000). Second, optimal seed replacement for IOPV maize varieties is 3 years as compared to annually or bi-annually with hybrids, but since there is no incentive for private companies to produce IOPV seed, this seed supply must be generated through other means. In Malawi, the government failed to pay farmers contracted under the smallholder seed multiplication scheme last year, causing farmer protests and loss of confidence.

There were problems in implementing the TIP, including a major mismatch between the rains and delivery of packages. The estimated direct production impact was negligible compared to earlier years. Levy and Barahona (2001) report that while some skeptics argued that the 1998-99 and 1999-2000 national output was solely the result of good weather, the methodology isolated production impact and indicated that (1) SP1 contributed around one-quarter of total maize produced by smallholder farmers in 1998-99; (2) SP2 contributed 15-30% of total maize produced by smallholder farmers in 1999-2000; (3) TIP was expected to contribute only 5% of total maize produced by smallholder farmers in 2000-01. They estimated that only 5 percent of smallholder farmers had enough food to last from the 2000 harvest until the 2001 harvest. National grain stocks were sold in 2001, and famine ensued in 2002.

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Table 1 -- Selected production and consumption statistics for maize case study countries, 1997-99

Country	Production 1997-99 ('000 t)	Maize area % of total cereal area	Average per capita consumption of maize as food (kg/yr)	Average % of maize used in human consumption
Kenya	2255	79	94	91
Malawi	1826	89	148	82
Zambia	818	78	140	85
Zimbabwe	1710	75	122	76
Ghana	1015	52	42	75
Nigeria	5419	22	34	55

Source: Aquino et al. (2001). Based on FAOSTAT.

Table 2 -- Percentage of national maize area in improved maize for case study countries, 1990, 1996 and 2000

Country	1990			1996			1999		
	OPVs %	Hybrids	All MVs	OPVs %	Hybrids	All MVs	OPVs %	Hybrids	All MVs
Kenya	8	62	70	7.5-9.5	62-64	71-73	2	85	87
Malawi	3	11	14	1-4.4	13-33	14-37	4	39	43
Zambia	5	72	77	0.6-0.7	18-22	19-23	3	62	65
Zimbabwe	0	96	96	0-4.5	82-91	82-96	9	91	100

Sources: Hassan et al. (2001), CIMMYT (2001); Manyong et al. (2002). Malawi Ministry of Agriculture, Lopez-Pereira and Morris, 1994, Smale and Phiri (1997). Figures for 1999 in Malawi include free input distributions

Table 3 --National maize area, yield and production growth rates during and after episodes of success

	Area		Yield			Production	
	Average ('000 ha)	Growth rate (%)	Average (mt/ha)	Growth rate (%)	Coefficient of variation	Average (mt)	Growth rate (%)
Episodes of success							
Kenya (1965-1980)	1330	1.86	1.31	1.44	0.09	1757970.6	3.30
Zimbabwe (1980-1989)	1293	-0.43	1.47	2.21	0.38	1905928.6	1.77
Zambia (1970-1989)	774	-3.07	1.59	4.92	0.18	1167970	1.85
Malawi (1983-1993)	1253	1.92	1.10	1.18	0.23	1379579.8	3.10
Decline (1990-2000)							
Kenya (1990-2000)	1420	-0.12	1.65	-1.32	0.12	2341964	-1.45
Zimbabwe (1990-2000)	1313	2.52	1.29	-2.75	0.36	1013827	-0.23
Zambia (1990-2000)	635	-1.56	1.60	-0.84	0.29	1722154	-2.41
Malawi (1994-2000)	1282	0.75	1.35	3.67	0.24	1753398.3	4.42

FAOSTAT data used for purposes of internal consistency.
Coefficient of yield variation adjusted for trend (Cuddy and Della Valle, 1978).
Notes: 1992 excluded for Zimbabwe, Zambia and Malawi because of extreme values.
In Malawi, with several years of good rainfall and infusions of free germplasm through
Starter Pack and other initiatives, growth rates are positive even during the decline (see Figure 2)

Table 4 -- Illustrative partial budget for smallholder maize producer in Malawi, during and after the episode of su

	1991		1996	
	Fertilized Hybrid Maize	Unfertilized Local Maize	Fertilized Hybrid Maize	Unfertilized Local Maize
	--constant 1991 Malawi Kwacha (MK)--			
Yield (kgs/ha)	2774	745	2774	745
Producer price(MK/kg)[1]	0.27	0.27	0.24	0.24
transport and harvesting costs/kg	0.04	0.04	0.04	0.04
Gross returns(MK/ha)	638.02	171.35	561.88	150.90
Seed costs[2] (MK/ha)	37.5	6.5	77.28	10.53
Fertilizer[3]	196.35	0	358.98	0
Credit charges[4]	28.06	0	174.50	0
Variable cost	261.91	6.50	610.75	10.53
Returns to land (MK/ha)	376.11	164.85	-48.88	140.37
Returns to land (USD/ha)	137.27	60.16	-17.84	51.23
Returns to labor (MK/day)[5]	6.07	3.23	-0.79	2.75
Returns to labor (USD/day)	2.21	1.18	-0.29	1.00

Source: Yield, harvesting, labor, wages from survey data summarized in Smale et al. (1991), for 420 farmers in major maize-producing regions of Malawi; 1996 seed prices from survey data summarized in Smale and Phiri (1997).Fertilizer cost per hectare from Benson (1997).

[1] The producer price is used here although the consumer price is relevant for most Malawian smallholder farmers, who are deficit producers of maize. Using the consumer price would increase

[2] 25 kgs/ha constant seeding rate

[3] At recommended rates of N-P-K. (96:40 nutrient kgs/ha)

[4] Credit was virtually unavailable for smallholder maize production in the 1996 survey, and interest rates charged by the Malawi Rural Finance Corporation ranged from 40-54 percent.

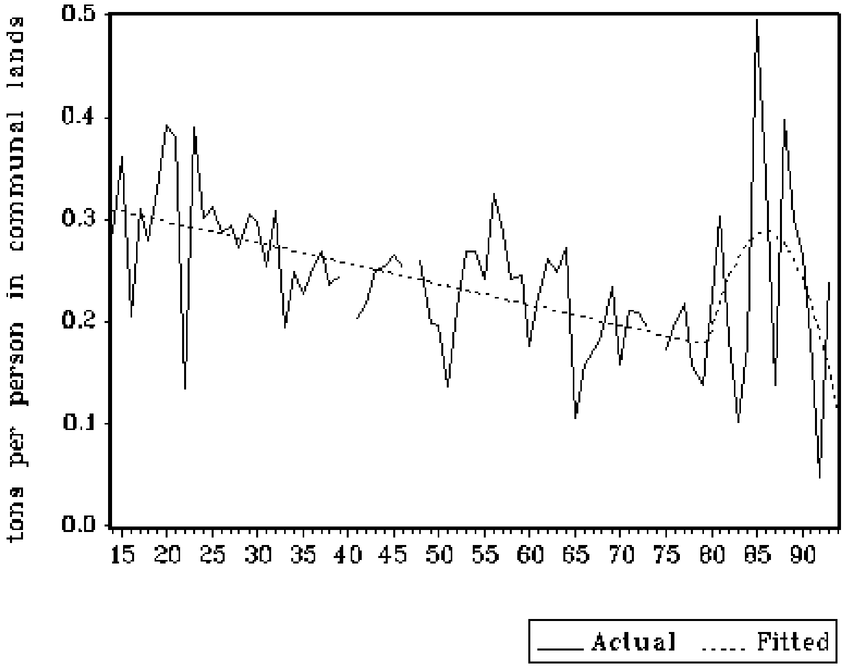
[5] 6-hour days, 62 person-days for hybrid maize, 51 person-days for unfertilized local maize.
Modal rural wage in 1991 of MK 1.3/day assumed not to have changed in real terms in 1996.
In 1996, MK 15=USD 1; in 1991, MK 2.74= USD 1.

Table 5 -- Returns to Labor, Daudawa Village, S. Kastina, 1973-4

Crop	Labor input without traction	Overall return to labor	Return to labor; peak labor period (June-July)
	(days/ha	(N/hour)	(N/hour)
Improved maize	526.3	0.33	1.05
Improved sorghum	400.5	0.17	0.53
Local sorghum	240.9	0.21	0.81
Improved cotton	516.9	0.07	0.25
Local cotton	526.3	0.04	0.17

Source: Norman, D., Simmonds, E., and Hays, H. 1982. Farming Systems in the Nigerian Savanna. Boulder, CO: Westview Press. Cited in Gilbert (1993).
Note: cotton prices were low on the world market at that time.

Figure 1. Per Capita Grain Production in African Communal Lands, Zimbabwe 1914-1994.



Source: computed from data in Annual Reports of the Chief Native Commissioner (presented in Mosley 1983); Ministry of Agriculture (1995).

Note: The spline function generating the trend estimates was:

$$Y_t = b + b_1(TREND_t) + b_3D(TREND_t - I) + b_4D(TREND_t - I)^2 + v_t$$

where Y_t is grain output per capita in Zimbabwe's communal lands in year t; *TREND* is a time trend; *I* is a constant equalling the value of the time trend variable at independence in 1980; *D* is a dummy variable taking on a value of zero before independence in 1980 and 1 otherwise. The term $_t$ is assumed to be independent and identically normally distributed with mean zero and constant variance. The estimated average annual change in per capita grain output is b_1 from 1914-1979 and $b_1 + b_3 + 2b_4(TREND\text{-}I)$ from 1980-1994. This specification allows for non-linearity in the trend after independence. F-test results rejected the assumption of linearity at the .001 significance level. Model estimation produced the following results (t-statistics in parentheses):

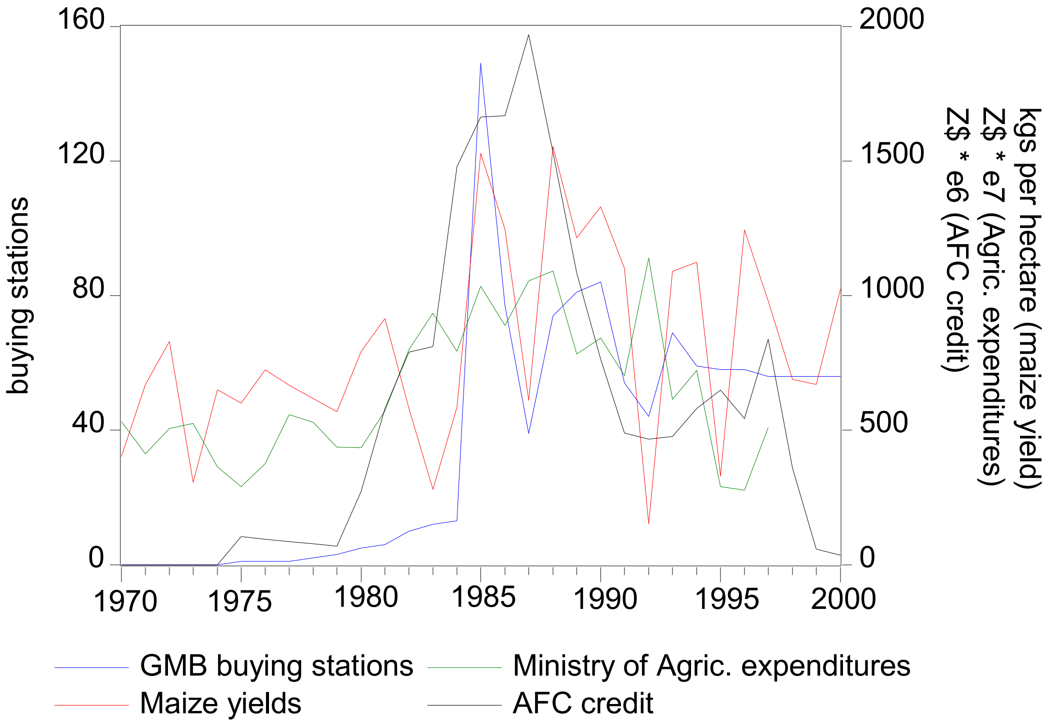
$$Y_t = 308.7 - 1.85(TREND_t) + 32.8(TREND_t\text{-}I) - 2.21(TREND_t\text{-}I)^2$$

(18.3) (-4.32) (3.99) (-3.77)

$R^2 = 0.23$
F = 8.99
DW = 2.21

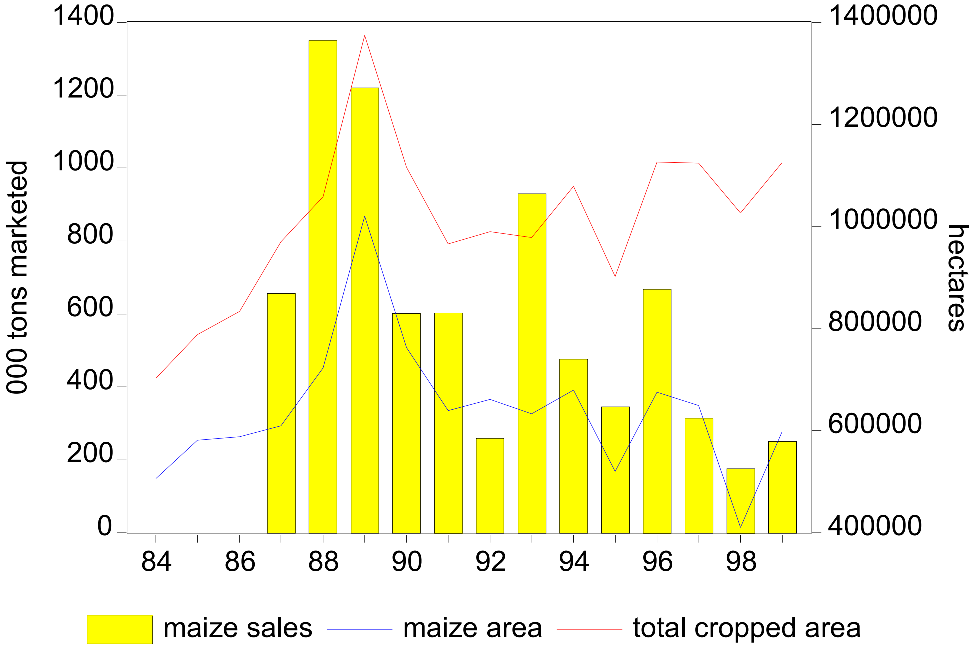
Results indicate that average annual change in grain production per capita was - 1.85 kgs from 1914-1979 and -1.12 kgs when evaluated at the mid-year of the post-independence period (1987).

Figure 2. Public expenditures supporting smallholder maize yields in Zimbabwe during episodes of success and decline, 1970 – 2000 (monetary values are in constant 2000 Zimbabwe Dollars)



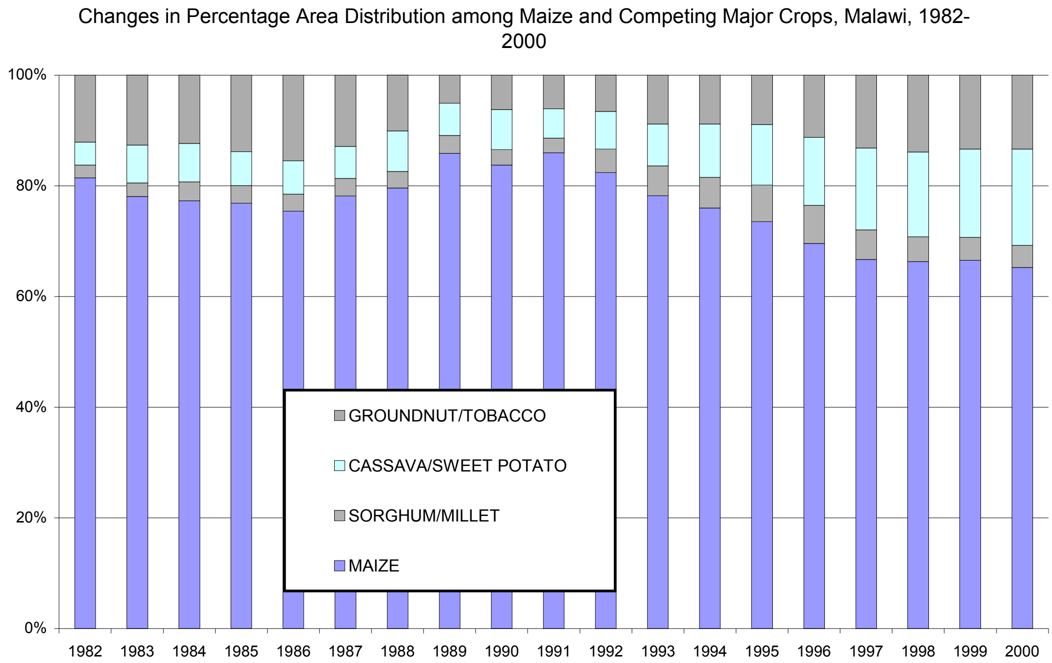
notes: GMB buying stations include main depots and collection points; Ministry of Agriculture expenditures include research and development, extension services, and allied services; AFC credit is the value of seasonal credit disbursed by the Agricultural Finance Corporation.
Sources: Agricultural Finance Corporation, Agricultural and Economic Review and Board papers, Harare office; Ministry of Lands, Agriculture and Rural Resettlement, 2001. The Agricultural Sector of Zimbabwe: Statistical Bulletin – 2001, Harare.

Figure 3. Maize Area and Maize Marketed by the Small-scale and Medium-scale Farming Sector, Zambia, 1980-1999.



Source: Crop Forecast Surveys, Central Statistics Office, Lusaka.

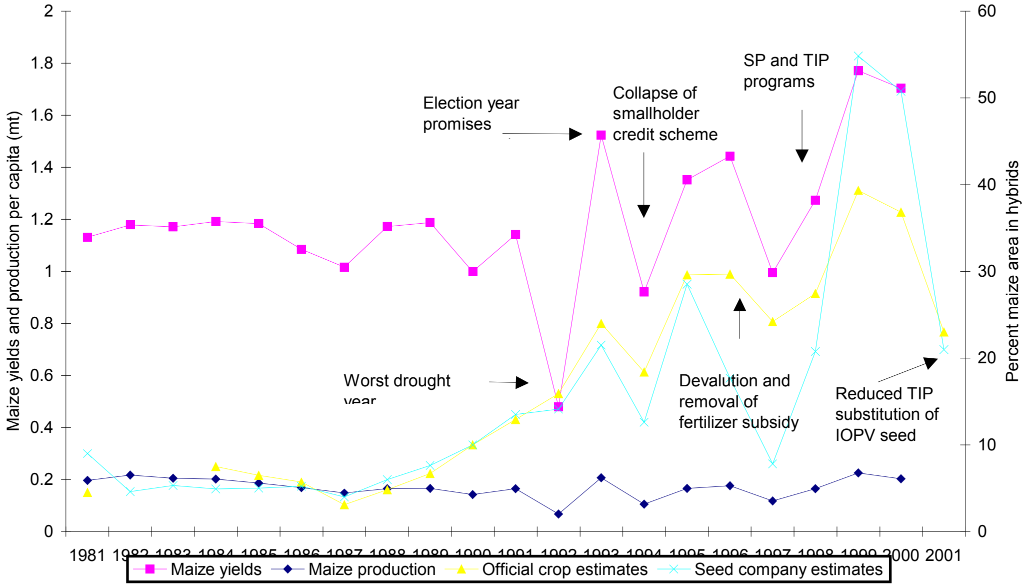
Figure 4 –



Source: Malawi Official Crop Estimates, 1982-2000

Figure 5 –

Hybrid maize diffusion, maize production, exogenous shocks and policy changes in Malawi, 1981-2001



Data sources: FAOSTAT, National Seed and Cotton Milling, Malawi Ministry of Agriculture (unpublished data), Nakhumwa (2002).