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THE IMPACT OF INVESTMENTS IN MAIZE RESEARCH AND DISSEMINATION IN ZAMBIA: PRELIMINARY RESULTS

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1. INTRODUCTION

Michigan State University (MSU) is currently assessing the impact of agricultural research in seven African countries, chosen to represent countries located in a variety of agro-ecological zones whose research systems have received significant levels of USAID funding. The countries and commodities under study are Cameroon (maize, cowpea, sorghum), Kenya (maize, wheat), Malawi(maize), Mali (maize), Niger (sorghum, cowpea, millet), Uganda (oilseeds), and Zambia (maize). The research being undertaken by MSU is one of a series of studies recently commissioned to help USAID and the U.S. Congress analyze the effectiveness of aid given to strengthen national agricultural research systems in Africa.

2. ZAMBIA CASE STUDY

In Zambia, MSU is collaborating with the Ministry of Agriculture, Food and Fisheries (MOAFF) and the University of Zambia's Rural Development Studies Bureau (RDSB) to assess the impact of investments in maize research and dissemination made during the late 1970s and early 1980s. This research resulted in the release of ten new hybrids and open-pollinated varieties between 1984-88. Major support to maize research and dissemination has come from the Government of Zambia (GRZ), the Food and Agriculture Organization/United Nations Development Program (FAO/UNDP)(1978-92), the Swedish International Development Authority (SIDA)(1982-present), and the United States Agency for International Development (USAID)(1982-87).

2.1. Research Objectives

The specific objectives of the Zambia study are:

1) To calculate the rate of return to previous investments by the GRZ and donors to maize technology development and dissemination in Zambia;

2) To determine the distribution of maize research benefits between consumers and producers, and between different producer groups;

3) To examine the impact of key institutional, organizational and policy factors on maize research and technology transfer; and

4) To analyze the implications of changes in maize sector pricing and marketing policies for agricultural research strategy and for complementary investments.

Field research for the study began in December, 1991 and will continue through November, 1992.

2.2. Methodology

2.2.1. Index Number/Benefit-Cost Approach

An index number/benefit-cost approach is used to calculate an average rate of return (ARR) and the distribution of benefits from maize research and complementary investments. Figure 1 is a simplified version of the benefit-cost spreadsheet used to organize information on maize area, production, price and the costs of production, research and complementary investments under two scenarios; with and without the additional investments associated with development and dissemination of the new maize hybrids and varieties. A stream of net benefits is derived for each year by subtracting the additional costs from the additional benefits generated by the new technology. The internal rate of return (IRR) is the discount rate that just makes the net present value of the net benefit stream equal zero. It represents the maximum amount of interest the research project could pay for the resources used in order to recover its investment and operating expenses and just break even (Gittinger, 1982).

The method used differs from standard calculations of rates of return to research, which include as costs only additional production costs and expenditures on research. The Zambia study also includes as costs investments in complementary institutions such as the seed industry, extension and the marketing system. The benefits usually attributed to research, increased yields from new maize varieties, and increased area planted to improved varieties, are more correctly perceived as the products of an array of complementary institutions including research, extension, the seed industry, extension, credit, and the marketing system, which together develop and disseminate technology to farmers. Although multivariate regression techniques are often used in other problems to disaggregate the impacts of different variables, they have not been very reliable in analyzing the relative impacts of research and other investments because of multicollinearity problems. The rate of return calculated in the Zambia study is considered to be a return to investments in the bundle of complementary institutions which generated and disseminated the new maize technology.

Sensitivity analysis of the rate of return, together with calculation of domestic resource costs under different market development scenarios, will be used to analyze the implications of changes in maize sector pricing and marketing policies for agricultural research strategy and for complementary investments.

2.2.2. Maize Adoption Survey

The rate and extent of adoption of new technology is one of the most critical inputs to the rate of return analysis. To collect data on adoption of the new maize hybrids and varieties and factors influencing farmer adoption decisions, a survey of over 450 small (< 5 hectares) and medium-scale (5-20 hectares) farmers located in the principal maize-growing areas of Zambia's three agro-ecological zones was carried out between April and July, 1992. The sample frame used was one developed by the Central Statistical Office (CSO) for its agricultural survey. The location of sample

Figure 1: Calculating the ROR: Benefit-Cost Analysis Method

Category	78	79	80	81	82	83	84	85	86	87	88	89	90-2000
BENEFITS													
Without Research													
Area in local varieties													
Yield, local varieties													
Price, local varieties													
Production value (1)													
With Research													
Area in local varieties													
Yield, local varieties													
Production, local varieties													
Price, local varieties													
Production value, local varieties (2)													
Area in improved varieties													
Yield, improved varieties													
Production, improved varieties													
Category													
Price, improved varieties													
Production value, improved varieties (3)													
ADDITIONAL BENEFIT (4)=(3)+(2)-(1)													
COSTS													
Without Research													
Production Costs (5)													
With Research													
Production, research, other costs (6)													
ADDITIONAL COSTS (7)=(6)-(5)													
NET BENEFIT (8)=(4)-(7)													

INTERNAL RATE OF RETURN (%) = the discount rate that just makes the net present value of the net benefit stream equal zero.

[a]Crawford, 1991.

Standard Enumeration Areas is shown in Figure 2. Those interviewed were a stratified random subsample of farmers who participated in CSO's Agricultural Census earlier in the year.

2.2.3. Modified Agricultural Technology Management Systems Framework

A modified version of the Agricultural Technology Management Systems (ATMS) framework developed by Elliot *et al.* (1985) is being used to analyze the institutional process through which maize technology was developed and disseminated in Zambia. The components of the institutional analysis include:

(1) Sector Analysis. Assessment of the performance of the maize sector in general and identification of key institutions and policies affecting maize technology generation and transfer. Instrument: literature search.

(2) Functional Analysis. Description of the key institutions affecting maize and analysis of their key functions and interactions. Instruments: literature search, interviews with key informants.

(3) Events Analysis. Identification of key events in the chronology of maize technology development and diffusion and documentation of the role of institutions and policies in these events. Instruments: literature search, interviews with key informants.

(4) Policy Analysis. Description and analysis of the key macroeconomic, intersectoral, and agriculture sector policies which have had an impact on maize technology dissemination. Instruments: literature search, interviews with key informants.

3. IMPACTS OF INVESTMENTS IN MAIZE RESEARCH AND DISSEMINATION

3.1. Development of Improved Hybrids and Varieties

Eight hybrids and two open-pollinated varieties were released by the Research Branch between 1984-88. These included an improved version of the Zimbabwean hybrid SR-52, whose parent lines had become contaminated, resulting in a yield decline of 12-14 per cent. Other releases were shorter-season hybrids and open-pollinated varieties which were higher yielding than local varieties, incorporated resistance to streak virus and cob rot, and were tailored to Zambia's three major agro-ecological zones (Figure 2). Zone I is the driest region in the country, receiving between 600-800 mm rain/year; Zone II receives between 800-1000 mm/year, and Zone III, the high-rainfall area, receives over 1000 mm of rainfall annually. Table 1 describes the characteristics of the new hybrids and varieties in more detail.

Table 1: Characteristics of Zambian Maize Hybrids and Varieties

Type and Year Released	Days to Maturity	Yield in Tons/ha[a]	Target Area	Characteristics
MM 501 1984	130-135	6.0	Zones I, II Commercial Farmers	Single cross, white semi-dent; drought resistant; mod. resistant maize streak virus (MSV), rust, blight, cob rot
MM 502 1984	140-145	7.5	Zones II, III Commercial Farmers	Single cross, white semi-dent; multiple cobs; high resistance MSV; mod. resistance blight, cob rot
MM 504 1984	135-140	6.5	Zone I Commercial, Small Farmers	Three-way cross, white dent; Mod. drought tolerance; good resistance lodging; mod. res. MSV, rust, blight, cob rot
MM 601 1984	140-145	7.5	Zones II, III Commercial Farmers	Single cross, white dent; mod. drought tolerance; mod. resistance blight, rust, MSV, cob rot
MM 603/604 1984	145-150	7.0	Zones II, III Commercial Farmers	Three-way cross, white dent; multiple cobs; high resistance MSV, mod. resistance blight, rust, cob rot
MM 752 1984	155-160	8.0	Zones II, III Commercial Farmers	Single cross, white dent; susceptible lodging, MSV; mod. resistant rust, blight
MM 612 1988	155-160	7.0	Zones II, II Commercial Farmers	Double cross, white dent; mod. resistant MSV
MMV 600 1984	130-135	4.0-5.0	Zones I, II, III Small Farmers	Open-pollinated, white medium flint; resistant lodging, rust, blight, cob rot; drought tolerant
MMV 400	100-110	2.5-3.5	Zone I Small Farmers	Open pollinated, white hard flint; resistant blight, cob rot, MSV, lodging

[a] Projected farm yields under medium to high levels of management

3.2. Formulation of Location-Specific Agronomic Recommendations

On-farm research conducted by Adaptive Research Planning Teams (ARPT) resulted in the refinement of recommendation domains for the new hybrids and varieties. ARPT trials also showed that the rate of fertilizer application being recommended in some areas could be cut significantly without yield reduction.

3.3. Household Food Security

The availability of shorter-season maize varieties can improve the level of household food security in two ways. First, some of the new varieties can be harvested early as "green" maize and consumed during the hungry season, before other varieties and crops are ready for harvest. Second, small farmers frequently plant maize late because of labor constraints during the land preparation period, or because they plant other crops before maize. The shorter-season hybrids/varieties allow greater flexibility in the planting date without sacrificing yield, reducing the riskiness of maize production (particularly when inputs are used) for the small farmer.
Another dimension of the food security issue, however, is that encouragement of maize production in some areas has led farmers to shift away from production of more drought-resistant (thus less risky) subsistence crops that are more likely to be consumed by the family than sold on the market. ARPT evidence on the nutritional and food security impact of shifts to more maize-oriented cropping systems is mixed, but it is likely that adoption of improved maize has decreased household food security in at least some areas, particularly in Zone 1.

3.4. Strengthening the National Agricultural Research/Extension System (NARES)

Donor support to the maize sector has included significant funding for both long-term degree training and short courses for Zambian researchers. USAID's ZAMARE project alone trained 49 researchers and extensionists to M.S. or Ph.D. levels (USAID, 1991). Those trained who later had a direct impact on maize research included 1 Ph.D. maize breeder, 1 M.Sc. maize breeder, 1 M.Sc. maize agronomist, 1 M.Sc. farming systems agronomist and 1 M.Sc. farming system economist. In addition, the presence of long-term expatriate researchers provided opportunities for professional interaction and on-the-job training.

3.5. Development of a Reliable Maize Seed Production and Distribution System

Maize seed has been produced in Zambia since before independence in 1964. However, as maize production expanded in the 1970s and 1980s, the demand for quality maize seed, distributed in a timely way throughout the country, began to overwhelm the existing service (personal communication, Chibasa, 1992). Beginning in 1980, a semi-commercial seed company, Zamseed, was organized, with shares held by the GRZ (40%), Zambian Seed Producers Association (20%), Zambian Cooperative Federation (20%), Svaloef, a Swedish seed company (10%), and Swedfund (10%). SIDA has provided technical assistance to Zamseed from its inception to date. In 1990, Zamseed sold a total of 266,856 bags (50 kg) of certified maize seed. Hybrid seed for MM603 and MM604 is widely available throughout the country at planting time, although other hybrids and varieties are harder to obtain. Maize seed represents 70 per cent of total seed sales, and there has

been recent criticism that the company has over-concentrated on maize, with the result that quality seed for other crops is not available in quantity (ARPT, 1991).

4. EVIDENCE OF IMPACTS FROM MAIZE RESEARCH AND DISSEMINATION

4.1. Results from the Maize Adoption Survey

Three-quarters of farmers interviewed in the maize adoption survey were small landholders, with five hectares of land or less. The average farm size of all respondents was just over four hectares, although farmers who had grown improved maize at some time had slightly larger farms, averaging six hectares. One-third of survey respondents were women.

Half of the farmers in the sample used hand hoes as their sole means of land preparation. One-third used mainly oxen for land preparation, and ten per cent used a combination of hand hoes and oxen.

4.1.1. Improved Maize Hybrid/Variety Adoption

Farmers were asked to recall their cropping patterns during the period 1984-92. Virtually all of the farmers in the sample had grown maize at some time, whether local or improved, and over half had planted one or more of the improved Zambian hybrids or varieties at some time since 1984. The proportion of farmers trying improved hybrids or varieties varied by agro-ecological zone. In Zone II, the agro-ecological zone best suited to maize production, 67 per cent of farmers questioned had grown improved maize. Fifty-seven per cent of farmers in the high rainfall zone (Zone III) had tried improved maize, while only 33 per cent of farmers in low-rainfall Zone I had used them.

Use of improved hybrids and varieties also varied by farm size. While 89 per cent of medium-scale farmers (5-20 hectares) had tried the improved maize hybrids or varieties at some time, only 46 per cent of small farmers (5 hectares and under) had.

Most of the farmers who tried improved maize hybrids or varieties once continued to use them in successive seasons, and can be considered adopters. Sample farmers who used improved maize hybrids and varieties had been planting them for nearly four seasons on average. Farmers using improved maize varieties or hybrids planted between 50 and 60 per cent of their total land area in improved maize.

4.1.2. Area and Rate of Maize Adoption

The estimated total area under maize in Zambia, including local, improved and imported varieties, was 564,000 hectares in 1983. Total maize area climbed to almost 800,000 hectares in the late 80s, but has declined since then (Central Statistical Office, 1992) (Table 2).

Table 2: Improved Maize Hybrid/Variety Adoption 1983-91

	1983	1984	1985	1986	1987	1988	1989	1990	1991
Total Maize Area[a] (ha)	564,000	575,600	532,400	659,000	691,500	797,300	667,865	578,815	472,315
Total Improved Maize Area[b] (ha)	0	57,560	177,822	288,642	358,889	450,475	433,444	371,020	290,473
Improved Maize/ Total Maize Area (%)	0	10.0	33.4	43.8	51.9	56.5	64.9	64.1	61.5

[a] Central Statistical Office estimates
[b] Estimated from MSU/MOAFF/RDSB Adoption Survey data

Based on results from the adoption survey, it is estimated that approximately 10 per cent of the total maize area was planted in improved hybrids or varieties in 1984, the first season that any of them was available to farmers (Table 2). The adoption rate climbed steadily through the late 1980s, peaking at 65 per cent of total area in 1989, then fell slightly in the 1991/92 season. The area planted to improved hybrids and varieties varied by agro-ecological zone. The proportion in improved maize was lowest in Zone 1, where only one-quarter of total maize area was planted to improved hybrids and varieties, and highest in Zone II, where three-quarters of all maize area was planted in Zambian improved maize by 1990.

In terms of actual hectares planted to improved maize (Table 2), improved maize hectarage more than quadrupled between 1984 and 1986, increased by half again between 1986 and 1989, and declined together with overall maize area since 1989.

The most widely adopted releases are MM604, MM603, MM752 and MM612. These four hybrids together accounted for 90 per cent of all maize seed sold by Zambia Seed Company (Zamseed) in 1991. The open-pollinated varieties, which were the products of the USAID maize research program, have not been widely adopted. MMV400 and MMV600 accounted for only two and one per cent, respectively, of Zamseed sales last year (Zamseed, 1991).

4.1.3. Yields

Although researchers projected that the improved maize varieties would yield between 4-8 tons per hectare under medium to high management by farmers, actual yield increases realized by small- and medium-scale farmers appear to have been much less. However, there was a pronounced jump in

yields for small- and medium-scale farmers beginning in the 1985 season, when most of the new hybrids and varieties became available. Yields rose from 1.8-2.0 tons/ha to 2.2-2.4 ton/ha, an increase of about 20 per cent, and have fluctuated around this level since.

The relatively low yields achieved compared to potential may be attributable in part to an increase in the number of smaller farmers planting maize, given their more limited access to fertilizer and lower management skills. Shortage of labor is particularly constraining on smaller farms, and there is a tendency for farmers to plant more land than they can adequately weed, with lower yields resulting. Another contributing factor is that some small farmers may be replanting part of their hybrid seed rather than purchasing it each season.

4.1.4. Influence of Policies and Complementary Institutions on Improved Maize Adoption

By any standard, the uptake of improved maize hybrids and varieties in Zambia has been rapid. The case of Zambia can be contrasted to Malawi, which is agro-ecologically similar but which has never had more than 20 per cent of aggregate maize area sown to improved hybrids or open-pollinated varieties (Smale, 1991).

A major reason behind the rapid adoption was the fact that Zambia had an effective seed multiplication and distribution mechanism that was able to get the improved hybrids and varieties out to farmers very quickly after their release. By 1985, Zamseed was already marketing all of the new hybrids and varieties released by researchers the previous year, although the available selection of maize hybrids/varieties has narrowed since then.

Second, most of the farmers who adopted improved maize had relatively good access to institutions which could be expected to facilitate maize adoption. Over half of the improved maize growers had been visited by extension agents, half had also received credit at some time, a striking 89 per cent said that they had applied fertilizer to their improved maize, and 72 per cent had marketed improved maize.

Third, and very importantly, maize adoption by farmers in Zambia has been driven to a large extent by the policy environment created by the former government. The overriding objective of these policies was to encourage domestic maize production in order to provide maize meal at inexpensive prices to urban Zambians. To encourage production, producer prices for maize were fixed, and in most years were subsidized above world market levels. Prices were uniform across the country, with government subsidization of transport costs. Fertilizer was also heavily subsidized, at levels up to 82 per cent of landed costs (Jansen, 1990). By 1990, the estimated cost of these policies had risen to 3.4 billion kwacha. Subsidies to consumers represented 40 per cent of the total bill, marketing another 40 per cent, and fertilizer 20 per cent (GRZ, 1990).

As an indication of the importance of these policies, the breakdown of the maize support system in the late 1980s was marked by the beginning of a declining trend in the total area planted to maize. At this time real producer prices dropped below world levels, fertilizer subsidies were reduced, and there was an increase in problems such as late delivery of fertilizer and payment for produce.

4.2. Preliminary Economic Rate of Return

In Zambia, an economic rate of return was calculated to the investments in research, extension and the seed industry made by the GRZ and various donors, with a reference period of 1978-2000. Preliminary results indicate that the rate of return to this bundle of investments is extremely high, exceeding 100 per cent. An important factor behind the high ROR is that, unlike other countries, where improved seed and fertilizer have been promoted together as a package, in Zambia the promotion of fertilizer use in maize preceded the development of the new hybrids and varieties. Starting in the 1970s, the Lima program of the extension service encouraged farmers to apply fertilizer to SR-52. As a result, farmers adopting the new hybrids and varieties incurred virtually no increase in production costs, since they were previously using fertilizer.

5. CONCLUSION: IMPACT OF MAIZE RESEARCH AND OTHER INVESTMENTS IN ZAMBIA

Four conclusions emerge from the Zambia case study at this preliminary stage. First, the rapid development of improved maize hybrids and varieties was facilitated by sustained support of the breeding program by GRZ and donor agencies. The principal breeder, Dr. Dusan Ristanovic, came to Zambia originally in the late 1970s as part of a Yugoslav aid project, but has been funded continuously since 1982 by SIDA. The maize breeding component of USAID's ZAMARE project (1982-87), although short in duration, was effective because USAID personnel coordinated with and strengthened the existing program. The USAID breeder focused on the development of open-pollinated lines, culminating in the release of two varieties and the selection of inbred lines which were later used in hybrid development, the focus of the SIDA-funded project. These projects also provided M.S. and Ph.D.-level training for the principal Zambian maize breeders and agronomists who currently form the core of the program.

Second, assessing the specific impact of research investments is not easy, because the success of research, measured in increased yields and areas planted to improved technology, is heavily dependent on institutions that facilitate the adoption of new technology by the farmers. It is very difficult to separate the contributions of research from those of complementary institutions and the policy environment which facilitate adoption.

Adoption of improved maize in Zambia was rapid and extensive, but the rates give a distorted impression of the economic impact of the technology because adoption was induced by an unsustainable institutional and policy environment. Many changes have already been made, and by the 1992-93 season, the maize marketing system will be almost fully liberalized. Fertilizer subsidies have been removed, and producer and consumer prices will reflect commodity transport and storage costs.

Other costs associated with the heavy orientation to maize are now becoming evident. For almost twenty years, research, extension, and seed production have all been focused primarily on maize. With the changing policy environment, which will encourage a shift in cropping patterns, the lack of readily available technology, seeds and credit facilities for other crops poses major problems for Zambian farmers.

Third, considering the influence of non-research institutions on technology adoption, it is important for a National Agricultural Research/Extension System (NARES) to view itself not as an isolated entity, but as one having a vital interest in knowing how the institutional environment, including the seed industry and the extension system, would support (or not) the products of current and potential research. This support is necessary if investments in NARES are to have a measurable impact.

Finally, rates of return and adoption statistics are only partial indicators of the success of investments in research, and can be misleading guides to future investment unless they are used in conjunction with an analysis of the institutions influencing technology generation and diffusion. Past rate of return studies have frequently attributed benefits associated with new technology entirely to investments in research, when in fact successful adoption of technology depends on a range of complementary institutions.

More important than deriving a summary number as a measure of research "success" is understanding the **process** that generated and disseminated adopted technology. Today's research systems include national, regional and international players; an ROR or adoption rate cannot tell a policy-maker about the relative and differing contributions of each to technology development, nor suggest how funding should be allocated between them. Neither can the summary numbers alone help policy-makers understand research investments within the context of investments in the panorama of rural institutions, whose functions and determinants of success are so tightly bound up in one another.

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ENDNOTES

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