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THE IMPACT OF MAIZE RESEARCH IN ZAMBIA: METHODOLOGY AND PRELIMINARY RESULTS

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EXECUTIVE SUMMARY

OVERVIEW OF THE MICHIGAN STATE UNIVERSITY AGRICULTURAL TECHNOLOGY IMPACT AND POLICY ASSESSMENT STUDY

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 understand the effect of aid given to strengthen national agricultural research systems in Africa.

Recently there has been increased interest in assessing the impact of agricultural research. Why? Within the last two decades, African governments and donors have sharply increased outlays on agricultural research. Since 1970, real expenditures on African agricultural research have quadrupled, from $103 million to well over $400 million. These investments were undertaken because it was felt that generation and diffusion of agricultural technology was the key to increasing agricultural productivity, which in turn can facilitate structural transformation and promote overall economic development. But, despite this investment, African agricultural productivity has been largely stagnant for the past twenty years, and has not kept up with spiraling population growth.

Are weak National Agricultural Research Systems (NARS) to blame for low agricultural productivity in Africa? How can the performance of NARS be evaluated? These are two of the critical questions in the debate. The Michigan State project began by reviewing evaluations of agricultural research worldwide, and found that very little is known about the payoffs to African agricultural research. Less than a dozen rate of return (ROR) studies were

identified in Africa, compared to 79 in developed countries, 66 in Latin America and 25 in Asia (Oehmke **et al.**, 1991).

Of the rate of return studies which are available for Africa (Table 1), the results suggest that research in Africa can have acceptable returns, similar to studies from other parts of the world, with rates of return ranging from 30 to over 60 per cent. How can these rates be interpreted, in view of the concerns about African agricultural productivity?

Rate of Return as a Measure of Project Worth

First, what **is** a rate of return? It is one measure used to evaluate long-term investments. The rate of return is a single number which summarizes the time pattern and relative sizes of the benefits and costs associated with the project. The number can be thought of as the rate of interest which a bank would have to pay to generate the same net return as the research project. Once the ROR has been determined, it can be compared to the prevailing interest rate or some other measure of the opportunity cost of capital to determine the relative attractiveness of the investment. If the ROR exceeds the cost of capital, the project has yielded above average returns and it is considered to be economically successful.

The rate of return to a research project can be calculated as an average or a marginal rate. The average rate of return (ARR) takes the research expenditure as given and calculates a rate of return to the project in its entirety. This provides information on which projects were successful. However, it may not be possible to determine if the allocation of research dollars among projects was appropriate using the ARR measure, since according to economic theory, the optimal allocation of research resources occurs when the last dollar spent on each project generates the same returns.

Table 1: Returns to Agricultural Research in Africa

AUTHOR	YEAR	COUNTRY	COMMODITY	PERIOD	RESULT (%)
Abidogun	1982	Nigeria	Cocoa	--	42
Evenson	1987	Africa-wide	Maize, staple crops	1962-80	30-40
Norgaard	1988	Africa	Cassava	1977-2003	149:1 [1]
Schwartz **et al.**	1989	Senegal	Cowpea	1981-2015	63
Karanja	1990	Kenya	Maize	1955-88	40-60
Mazzucato	1991	Kenya	Maize	1955-88	58-60
Makau	1984	Kenya	Wheat	1924-74	33
Ahmed and Sanders	1991	Sudan	Sorghum	1977-2013	22-39

[1] Benefit-cost analysis

The marginal rate of return (MRR) quantifies the return to the last dollar invested in the research project, but is more difficult to estimate in terms of data requirements. It is usually determined through econometric estimation of the algebraic relationship between research expenditures and a supply function.

Practically speaking, how does one go about calculating a rate of return, and what kinds of information are needed? The benefit-cost method is one way to calculate the average rate of return (ARR) Figure 1 is a simplified version of the spreadsheet which is being used to calculate the returns to maize research investments in Zambia. In the Zambian case, information is being collected about maize area, production, price, and the costs of production, research and complementary investments under two scenarios; with and without the research investment. 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).

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

CATEGORY	79	80	81	82	83	84	85	86	87	88	89
BENEFITS											
Without Research											
Area in local varieties,											
Yield, local varieties,											
Production											
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											
Price, improved varieties											

Figure 1, cont.

CATEGORY	81	82	83	84	85	86	87	88	89	90	91
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.

Rate of Return: to Agricultural Research, or to Research Plus Complementary Investments?

Returning to the studies of rate of return to agricultural research in Africa (Table 1), if rates of return to research are so high, why are African agricultural economies doing so poorly? Let us look more closely at what's being measured by the rate of return. The benefits being considered in the Zambian case are increased yields from the new maize hybrids and varieties, and increased areas planted to varieties. A central question is whether it is fair to attribute these benefits to research alone, Because that is what many of the rates of return to research actually do. However, even when researchers develop winning technologies, they are dependent on a series of complementary institutions -- including extension, credit, and the marketing system for inputs and outputs, to ensure that the technology gets out to and is adopted by the farmers. The rate of return is actually to the whole "bundle" of investments that go into developing and disseminating a technology. It is very difficult, even using sophisticated multivariate statistical analysis, to disaggregate the contribution of research from the contributions of complementary investments which facilitate farmer adoption of new technology.

The common denominator of the seven country studies being carried out is the calculation of an ex-post rate of return. Assuming that a rate of return is really a return to a bundle of investments, the Zambia case study and other MSU studies try to identify the essential complementary investments that aided development and dissemination of the new technology, and include their costs in the rate of return calculations, not just the cost of research programs. Apart from the static rate of return calculation, several of the studies also consider issues affecting the dynamics of technology development and transfer: for example, how coordination and sequencing of agricultural investments and policies, and how the interaction of different interest groups with

a stake in the output of agricultural research, affect the technology development and transfer process, and the distribution of benefits from this process.

ZAMBIA CASE STUDY

Research Objectives

In Zambia, MSU is collaborating with the Ministry of Agriculture and the University of Zambia's Rural Development Studies Bureau to assess the impact of investments in maize research made during the late 1970s and early 1980s. This research resulted in the release of seven new maize hybrids and two new open-pollinated varieties of maize. The major donors to maize research have been SIDA, USAID and FAO/UNDP.

The newly developed hybrids and open-pollinated varieties included a clean version of the Zimbabwean variety SR-52 (whose parent lines had become contaminated, resulting in yield declines of between 12-14 per cent), shorter-season hybrids, and hybrids and open-pollinated varieties which were higher yielding than local varieties and tailored to different 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 1000mm of rainfall. Table 2 describes the characteristics of the hybrids and varieties that are the focal point of the case study.

The specific objectives of the Zambia case study and the methods used to attain these are:

1) To calculate the rate of return to previous investments by USAID, Government of Zambia (GRZ) and other donors to maize research in Zambia.

   Method: index number/benefit-cost approach.

   Data sources: adoption survey of maize producers, government and donor records, literature review.

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

Method: index number/benefit-cost approach

Data sources: adoption survey, government and donor records, literature review

3) To examine the impact of key institutional, organizational and policy factors on maize research and technology transfer.
Method: modified Agricultural Technology Management Systems framework
Data sources: personal interviews with key informants, adoption survey, literature review

4) To analyze the implications of changes in maize sector pricing and marketing policies for agricultural research strategy and for complementary investments.
Method: sensitivity analysis of ROR, calculation of Domestic Resource Costs (DRCs), institutional analysis using ATMS framework.
Data sources: government and donor records, personal interviews with key informants

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

Preliminary Results from the Maize Adoption Survey

General

A survey of over 450 small and medium-scale farmers located in the principal maize-growing areas of the three agro-ecological zones was carried out between April and July of this year. The sample frame developed by the Central Statistical Office for its agricultural survey. Standard Enumeration Areas (SEAs) were stratified by agro-ecological zone, farm size and distance from service centers. Those interviewed were a randomly selected sub-sample of farmers who participated in the Central Statistical Office's Agricultural Census earlier in the year.

Three-quarters of farmers interviewed were small landholders, with 5 hectares of land or less. The average farm size of all

respondents was 4.2 hectares. Farmers who had grown improved maize at some time had slightly larger farms, averaging 6.24 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 about ten per cent used a combination of hand hoes and oxen.

Improved Maize Hybrid/Variety Adoption

Virtually all of the farmers in the sample had grown maize at some time, whether local or improved. Fifty-six per cent of farmers said that they had planted improved Zambian hybrids or varieties at some time between 1984-92. The proportion of farmers trying improved varieties varied by agro-ecological zone. In Zone II, the agro-ecological zone most suited to maize production, 67 per cent of farmers questioned had grown improved varieties. Fifty-seven per cent of farmers in the high rainfall zone (Zone III) had tried Mt. Makulu varieties, 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 at all had been planting them for 3.7 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.

Area and Rate of Maize Adoption

The estimated total area under maize in Zambia, including local, improved and imported varieties, was estimated at 564,000

hectares in 1983. Total maize area climbed to almost 800,000 hectares in the late 80s, but has declined since then (Table 3).

Based on results from the adoption survey, it is estimated that approximately 20 per cent of the total maize area was planted in improved hybrids or varieties in 1984, the first season that most of them were available to farmers (Table 3). 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 3), improved maize hectarage more than doubled between 1984 and 1986, increased again by one third between 1986 and 1989, and has declined together with the decline in overall maize area, since then.

Yields

Although researchers projected that the improved maize varieties would yield between 4-8 tons per hectare under medium to high management by farmers, the actual yield increases realized by small and medium-scale farmers appear to have been much less. There was a pronounced jump in yields for small and medium scale farmers beginning in the 1984/5 season, when most of the new hybrids and varieties became available. Yields rose from the 1.8-2.0 tons/ha range to the 2.2-2.4 ton/ha range, 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, with less access to fertilizer inputs or 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, particularly, may be replanting part of their hybrid seed rather than purchasing it each season.

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 and culturally 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). What accounts for this difference?

Part of the explanation is that Zambia had an effective seed multiplication and distribution mechanism that was able to get the new varieties out to farmers very quickly after their release. By 1985, Zamseed was already marketing all of the new varieties released by researchers the previous year.

Secondly, most of the farmers in our sample who adopted improved maize had relatively good access to other institutions which could be expected to facilitate maize adoption. Over half of 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.

And, very importantly, in Zambia maize adoption by farmers 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, meaning the government heavily subsidized transportation costs. Farmers received the same price for their maize regardless of whether they lived 4 or 400 kms from an urban

consumption center or the line of rail. Fertilizer was also heavily subsidized, with subsidies rising to levels of 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. Consumer subsidies represented 40 per cent of this, marketing another 40 per cent, and fertilizer subsidies were 20 per cent (GRZ, 1990).

As a rough indicator of the importance of these policies, the breakdown of the maize support system in the late 80s is marked by a decline in the total area planted to maize. At this time real producer prices began to decline below world levels, fertilizer subsidies were reduced, and there were problems such as late payment for produce.

In Zambia, it appears that government institutions and policies facilitated a magnitude and pattern of maize adoption that was unsustainable. It was simply unaffordable. 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 transport costs.

There are other costs associated with the heavy orientation to maize which are now becoming evident. Research, extension, and seed production have all been focused primarily on maize for a long time. With the changing policy environment, which will encourage a change in cropping patterns, the lack of readily available technology, seeds and credit facilities for other crops are major problems for Zambian farmers.

CONCLUSIONS: IMPLICATIONS OF IMPACT ASSESSMENT FOR NARS

Two main conclusions emerge from the Zambia case study at this preliminary stage. First, assessing the impact of research investments is not easy. If increased yields and areas planted using improved technology are the primary measures of research benefits, 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, facilitated by an unsustainable institutional and policy environment that drained government resources.

Second, considering the influence of non-research institutions on technology adoption, it is important for a NARS to view itself not as an isolated entity, but one having a vital interest in knowing how the institutional environment would support (or not) the products of current and potential research--since this support is necessary if investments in NARS are to have an impact. This could be as simple as ensuring whether, if new varieties of sorghum are developed, facilities exist for multiplication and marketing of the seed to farmers.

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Table 2: Characteristics of Zambian Maize Hybrids and Varieties

TYPE AND YEAR RELEASED	DAYS TO MATURITY	YIELD IN TONS/HA*	TARGET AREA	CHARACTER-ISTICS
MM 501 1984	130-135	6.0	Zones I, II Commercial Farmers	Single cross, white semi-dent; drought resistant; mod. resistant 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

Table 2, continued

TYPE AND YEAR RELEASED	DAYS TO MATURITY	YIELD IN TONS/HA*	TARGET AREA	CHARACTER-ISTICS
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 1984	100-110	2.5-3.5	Zone I Small Farmers	Open pollinated, white hard flint; resistant blight, cob rot, MSV, lodging

* Projected farm yields under medium to high levels of management

Table 3: Improved Maize Hybrid/Variety Adoption 1983-91

	1983	1984	1985	1986	1987	1988	1989	1990	1991
Total Maize Area* (ha)	564,000	575,600	532,400	659,000	691,500	797,300	667,865	578,815	472,315
Total Improved Maize Area** (ha)	0	117,918	177,822	288,642	358,889	450,475	433,444	371,020	290,473
Improved Maize/ Total Maize Area (%)	0	20.5	33.4	43.8	51.9	56.5	64.9	64.1	61.5

* Central Statistical Office estimates

** Estimated from MSU Adoption Survey data