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The Impact of Agricultural Technology in Sub-Saharan Africa: A Synthesis of Symposium Findings

by

James F. Oehmke and Eric W. Crawford

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**Department of Agricultural Economics
Department of Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan 48824**

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THE IMPACT OF AGRICULTURAL TECHNOLOGY IN SUB-SAHARAN AFRICA:

A SYNTHESIS OF SYMPOSIUM FINDINGS

by

James F. Oehmke and Eric W. Crawford

March, 1993

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EXECUTIVE SUMMARY

Current perceptions of the impact of technology development and transfer (TDT) are often negative, describing few links between TDT and income-generating activity. To inform TDT investment decisions, USAID commissioned a set of studies to measure the people-level impacts of TDT in sub-Saharan Africa, as well as the accomplishments of TDT in achieving national-level impacts. The Symposium on the Impact of Technology on Agricultural Transformation in Sub-Saharan Africa funded by AID/AFR/ARTS and AID/RD/EID under the Michigan State University Food Security Cooperative Agreements, was held in Washington, D.C., Oct. 14-16, 1992, to report on results from these and other relevant impact assessments. A primary purpose of the symposium was to present evidence which would either confirm or contradict the perception that the accomplishments of TDT were insufficient to justify continued funding. A secondary objective was to consider the adequacy of available analytical tools for impact assessment.

The rate of return (ROR) is the most commonly used valuative measure of investments in technology development and transfer. The ROR assessments generally find positive RORs of an economically important magnitude. These findings provide a direct contrast to the negative comments about African agricultural research which have permeated recent discussions. Examined as a group, the estimated RORs support the proposition that African agricultural research has had people-level impacts, and that these impacts are large enough to justify the level of investment that led to the impacts.

An important part of the impact assessment story is the analysis of factors that had a positive or negative effect on the impact of TDT. Five major factors emerged from the studies presented and comments by symposium participants: agroclimatic conditions, civil unrest, research system performance, policy, and markets.

Progress has been made in moving forward with the process of TDT, in spite of adverse conditions. This progress includes enhancing the capabilities of national, regional and international institutions to generate new techniques, pushing forward the technology frontier, transferring technology, and increasing productivity both in farm production and post-harvest activities. Activities such as structural adjustment, improvements in agricultural and macroeconomic policy, greater reliance on democracy and capitalism, investments in infrastructure, and a greater willingness to work with the private sector have increased the potential for TDT to have significant impact.

Given the importance of raising productivity in agriculture as a step towards agricultural transformation, continued investment in agricultural TDT is merited. The evidence of impact achieved from previous investments shows that those investments have paid off. Coupled with the evidence of beneficial changes in the macroeconomic policy environment in many countries, this provides the basis for expecting that future investments will pay off.

Despite the conclusion that previous investments in TDT have had meaningful impacts, these investments have not always been used to maximum effectiveness. Prioritizing the scope and scale of TDT activities, financial sustainability, and agricultural sustainability can improve the effectiveness of TDT activities. What is perhaps unique about the symposium is the movement towards a commodity sector perspective as the next logical step toward including more demand-side considerations in the TDT agenda.

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James F. Oehmke
Eric W. Crawford[2]

1. BACKGROUND

1.1 Justification

Over the past fifteen years, USAID and other donors have made considerable investments in African technology development and transfer (TDT) activities. Yet obligations for TDT declined steadily from $ 55 million in 1986 to $ 35 million in 1991. This decline also reflects a decrease in the proportion of funds allocated to agricultural TDT from 34 percent of the allocation to all agricultural activities in 1986 to 14 percent in 1991.

Current perceptions of the impact of TDT are often negative, describing few links between TDT and income-generating activity. These perceptions are based in part on aggregate statistics, such as stagnant per capita food production in Africa, which are affected by population growth rates, war, drought, and a number of other factors in addition to TDT. The perceptions are also based in part on examples of real problems that agricultural TDT organizations face. The result is the dramatic decrease in USAID funding for TDT noted above.

In the Bureau for Africa's stated strategy for African development, TDT generates increases in agricultural productivity. In conjunction with other Development Fund for Africa (DFA) and national activities, increasing productivity will improve the well-being of poor farm families. It will stimulate agricultural transformation by releasing labor and capital from agriculture for employment in manufacturing and other non-agricultural activities, generating food sufficient to feed the agricultural and non-agricultural population at prices which these populations can afford, and providing increased income to farm families so that they may purchase non-agricultural products. Successful TDT activities contribute to this strategy by generating sustainable and resource-friendly increases in agricultural productivity. The magnitude of investment in TDT raises the question: Has TDT achieved the anticipated impacts? The marked reduction in USAID investment in TDT over the past decade raises a second question: how does investment in TDT compare to alternative uses of these resources?

Has technology development and transfer achieved impact? How does investment in technology development and transfer compare to alternative uses of resources?

To inform TDT investment decisions, USAID commissioned a set of studies to measure the people-level impacts of TDT in sub-Saharan Africa, as well as the accomplishments of TDT in achieving national level impacts. The former impacts may be measured by growth in individual income or other economic measures of welfare attributable to TDT, and are compared to expenditures by rate-of-return analysis. This activity resulted in the rate of return (ROR) studies coordinated by Michigan State University. National-level impacts may be measured by increases in agricultural output; land, labor or total factor productivity in agriculture; number of workers released from the agricultural sector; etc. The second activity commissioned by USAID, the maize research in Africa (MARIA) study contracted to USDA/OICD, examined evidence on agricultural output and productivity. USAID also gave CRSPs and IARCs a mandate to assess impacts of their activities.

The Symposium on the Impact of Technology in Sub-Saharan Africa was held in Washington, D.C. Oct. 14-16, 1992 to report results of impact assessments.

The Symposium on the Impact of Technology in Sub-Saharan Africa was held in Washington, D.C. Oct. 14-16, 1992, funded by AID/AFR/ARTS and AID/RD/EID under the Michigan State University Food Security Cooperative Agreements, to report on results from these and other relevant impact assessments. A primary purpose of the symposium was to present evidence which would either confirm or contradict the perception that the accomplishments of TDT were insufficient to justify continued funding. A secondary objective was to consider the adequacy of available analytical tools for impact assessment.

1.2 Objectives of this Report

In synthesizing the results of presentations and deliberations at the symposium, the current document has two objectives:

1. To summarize and interpret the evidence presented on the impact of TDT in sub-Saharan Africa.

2. To draw lessons which will improve the efficiency of future investment in African TDT.

1.3 Coverage

The current document draws on the papers, panels, and audience comments of the symposium. Every attempt has been made to be faithful to the substance and tenor of the symposium. The types of papers presented include impact assessments from the national perspective, impact assessments by IARCs and CRSPs, and regional and continent-wide examinations of productivity changes. Lists of registrants, and of papers presented, are contained in Annexes 1 and 2, respectively.

2. THE IMPACTS OF INVESTMENTS IN AGRICULTURAL TDT

2.1 What are the Potential Impacts of TDT?

TDT is a process characterized by four, sequential stages: creation of the institutional capacity to develop improved techniques of production, expansion of the technology frontier, transfer of technology to the users, and sustainable changes in long-term productivity. It is the last of these which may lead to people-level impacts, such as improvements in food security or increased incomes. It also is an important part of an environment which facilitates agricultural transformation.

TDT is a process characterized by four, sequential stages: creation of the institutional capacity to develop improved techniques of production, expansion of the technology frontier, transfer of technology to the users, and sustainable changes in long-term productivity.

Agricultural transformation begins with a shift away from subsistence farming. This shift is often generated by an increase in agricultural productivity, although off-farm changes such as the creation or expansion of markets are usually concurrent. The productivity increase allows the average farm household to produce enough to feed themselves, as well as some surplus to trade or market. The marketable surplus increases farm income, allowing the farm household to purchase improved agricultural inputs and consumer goods from the non-agricultural sector. Improved inputs lead to further increases in agricultural productivity and output. At the same time, purchases of inputs and consumption goods stimulate development of the non-agricultural sector. The agricultural sector enhances this development by providing the rest of the economy with food, labor, and capital for investment. Increases in the welfare of farm households and contributions to the enhancement of income-generating activities in the non-agricultural sector are the most important, beneficial impacts of agricultural TDT.

Traditional indicators of research output, such as productivity of the research system or the discovery of new agricultural techniques (for example, as measured by the number of trials or number of varieties released), are not always good indicators of impact on farm income or agricultural transformation. They are important measures of progress in meeting the conditions necessary for impact. However, further investigation is necessary to quantify the impact of TDT on the welfare of Africans.

2.2 ROR Assessment Methods

The rate of return (ROR) is the most commonly used valuative measure of investments in technology development and transfer. This measure summarizes the benefits, costs and time frame of the activity in a single number. This number is easily compared to interest rates or other measures of the costs of obtaining funds, and in many cases is also comparable across projects. The benefits used in the appraisal of TDT investments are usually people-level benefits such as changes in income or other measures of household welfare.

The rate of return summarizes the benefits, costs and time frame of the TDT activity in a single number.

There are several other accomplishments of TDT that are not often counted as benefits, due to difficulties in quantifying the impact. These accomplishments include improvements in the status of women within the household, improvements in the environment and the sustainability of agricultural production, improvements in the human and institutional capacity for research, and improvements in equity (income distribution). The ROR studies presented in the symposium do not account directly for these other benefits, although evidence of progress in these areas was reported in some studies.

2.3 ROR Assessment Results

The ROR assessments generally find positive RORs of an economically important magnitude. This finding reverses the conventional wisdom for Africa.

The ROR assessments generally find positive RORs of an economically important magnitude. These findings are striking. They provide a direct contrast to the negative comments about African agricultural research which have permeated recent discussions. The exceptions in the current set of studies to the finding of positive RORs are the returns to date in Niger and Uganda. In Niger, Mazzucato estimates a positive ROR by extending the analysis through 2010 under the assumption that adoption of improved varieties is no higher than it is today. Uganda's lack of significant impact is a direct consequence of the political problems of the 1970's and early 1980's. The remainder of the studies find positive returns, ranging from 3 percent to date for cowpea in Cameroon (projected ROR of 15 percent through 1998) to 135 percent to date for maize in Mali. Examined as a group, the estimated RORs support the proposition that African agricultural research has had people-level impacts, and that these impacts are large enough to justify the level of investment that led to the impacts.

In presentations and discussions, alternative interpretations of the consistently high estimated RORs were examined. For example, an alternative hypothesis is that ROR studies focus primarily on success stories, and thus the available evidence is biased in favor of TDT. The countries and commodities in the USAID-sponsored studies were chosen to overcome this criticism: the choices included some examples of likely TDT successes (e.g. Kenyan maize), and some cases in which the conventional wisdom was that little impact was achieved (e.g. Niger). The countries to be included in the MSU studies were chosen by a stratified random sampling method, although the commodities were chosen largely on the basis of importance to the food system and/or the needs of the AID missions, national agricultural research systems, and Ministries of Agriculture. The regional evidence of Evenson and Judd relates measures of productivity to measures of all research funding, including successes and failures, and finds large positive RORs. Thus, while some bias in commodity selection may exist, it is not a likely explanation of the positive ROR results.

The two most important considerations in interpreting the general pattern of ROR results are the role of international organizations, and benefits to consumers. Since the ROR studies were undertaken from the perspective of national research systems, a conscious decision was made to include only those costs associated with the national research organization(s).[3] However, most of the TDT activities under evaluation benefitted at least from discussions with IARCs, CRSPs or regional networks, and many benefitted from access to international germplasm or direct importation of improved varieties. Consequently, the reported RORs are most accurately interpreted as indications of the return to investment in national research programs if the IARCs continue to function at their current level of effectiveness.

TDT can generate benefits in excess of the opportunity cost of the investment in these activities.

A second important consideration in interpreting the general pattern of ROR results is that the effects of TDT on prices are generally ignored. For smaller activities such as cowpea TDT in Senegal, or in an economy that is integrated into regional or world markets, these effects are probably small. For successful maize TDT in a closed economy, the effect may be to lower prices substantially. However, lower prices often provide net benefits for the poorest farmers, who are often net purchasers of food, and for subsistence farmers who consume most of their own production. Thus, lower prices are expected to have positive implications for equity.

TABLE 1. SUMMARY OF ROR STUDIES FOR AFRICAN AGRICULTURAL TDT.

AUTHOR(S)	YEAR	COUNTRY	COMMODITY	TIME PERIOD	ROR in %
EX POST STUDIES					
Abidogun	1982	Nigeria	Cocoa	-	42
Makau	1984	Kenya	Wheat	1924-74	33
Evenson	1987	Africa	Maize & Staple Crops	1962-80	30-40
Karanja	1990	Kenya	Maize	1955-1988	40-60
Mazzucato[b]	1991	Kenya	Maize	[a]	58-60
Mazzucato and Ly[b]	1992	Niger	Cowpea, Millet & Sorghum	1975-1991	< 0
Schwartz, Sterns & Oehmke	1992	Senegal	Cowpea	1981-1986	31-92
Sterns & Bernsten[b]	1992	Cameroon	Cowpea	1979-1992	3
Howard et al.[b]	1992	Zambia	Maize	1979-1991	21[c]
Laker-Ojok[b]	1992	Uganda	Sunflower, Cowpea & Soybean	1986-1991	< 0
Boughton[b]	1992	Mali	Maize	1969-1991	135

[a] Parameter estimation using 1955-1988 data, ROR for research undertaken in 1978 as an example.
[b] ROR study commissioned by USAID. Malawi study not available.
[c] Preliminary

Source: Oehmke, 1992. For references, see Annex 3.

Moreover, examples from developed countries consistently suggest that the benefits to consumers of lower prices and increased opportunities for consumption are the most important consequences of lower prices. Consequently, inclusion of the effect of TDT on prices and consumer welfare is expected to maintain or increase the estimated RORs.

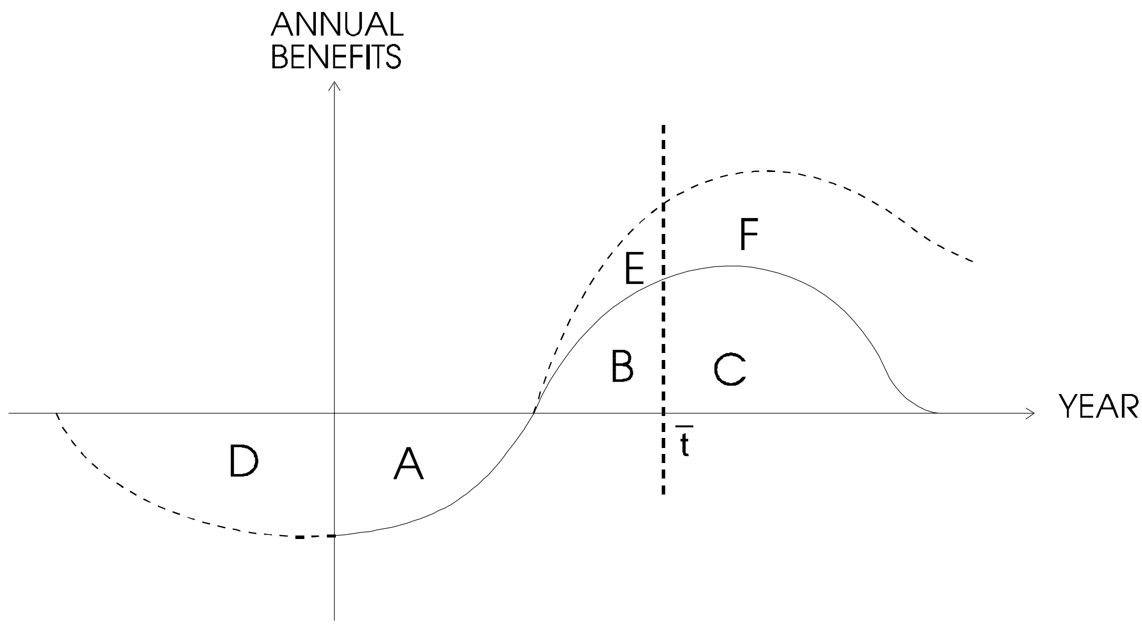
Thus, the conclusion remains: as a group, the studies indicate that TDT generates benefits in excess of the opportunity cost of the capital invested in these TDT activities. It is worth noting that this performance was achieved despite suboptimal conditions for TDT performance in many of the countries studied.

2.4 A Comparison of Methodologies Used

While each of the ROR studies uses the same conceptual background in assessing benefits and costs, there are several decisions about data collection, the scope of the investigation, and other critical variables that the investigator makes in the course of the study. These decisions can and do affect the estimated RORs. The more important issues are brought forward in this subsection.

Impact assessments are sensitive to the starting and ending points chosen by the evaluator. Technologies transferred within the last decade or two are likely to have continuing impacts. Particularly for young TDT systems, such as those in Africa, the bulk of the impacts of currently used technologies may come in the future. The role of the starting and ending points of the time frame is seen by examining the annual benefits of TDT (figure 1).

FIGURE 1. EFFECTS OF THE TIME FRAME ON ANNUAL NET BENEFITS



The origin marks the start of the evaluation period. In the early years, expenditures are made on TDT activities and new techniques are still in the development and transfer process. Thus impacts are small, leading to negative net benefits in the early years. This is depicted by area A. As varieties, breeds, or recommendations are transferred, impacts occur and the net benefits become positive, as depicted by area B + C. If area B + C is sufficiently larger than area A (the case shown), the ROR will be positive.

The choice of the evaluation period can affect the rate of return calculation.

Changes in the time frame used for evaluation may change the assessment. For example, suppose that time $\bar{t}$ denotes the present time. A young research program may be starting to have impacts at time $\bar{t}$, with the bulk of the impacts to come in the future. An assessment of impacts through time $\bar{t}$ by definition does not measure future impacts, and so measured benefits equal only area B. This will result in a negative measured rate of return. The difference between including projected future benefits and stopping the assessment at the present time is the only difference between Mazzucato and Ly's projected ROR in Niger of 7-21 percent through 2010, and their finding of negative returns to date (table 1). A similar example occurs when the costs included in the assessment are extended backward in time, perhaps because the project being evaluated is the second phase of an activity with earlier roots. In figure 1, this would cause the area D to be included as costs of the TDT, reducing the estimated ROR.

Another complication is that some benefits are difficult to quantify. For example, most of the ROR studies point to institution building as a desirable step to generating future impacts, but do not count the benefits of improved institutional capacity that accrue during the period evaluated. Increased institutional capacity may lead to further innovation and improved techniques, and consequently greater and longer-lasting impact. In figure 1 these additional benefits are represented by areas E and F. Including them in the analysis would raise the net benefits in later years and increase the estimated rate of return. For most of the studies presented in this symposium, benefits to consumers in the form of lower food prices are not included in the calculations, and are examples of non-measured benefits represented by areas E and F.

The individual studies also differ in how broadly the authors view the TDT activity in question, and what associated costs are included. For example, Schwartz et al. view the TDT process associated with "Operation Cowpea" as an integrated research, extension and input distribution activity. Consequently, measured program costs include research, extension and input distribution costs. In contrast, better quality data available in Kenya allow Karanja to separate statistically the effects of research from those of extension and seed distribution. Consequently, Karanja calculates an ROR to research alone. The studies' approaches to inclusion of research, extension, and other costs of the TDT process (such as input distribution or credit) are summarized in table 2.

The TDT programs under evaluation also differ in the type of outputs which they produce. For example, in Uganda, the devastation of the civil war meant that the first objective was to rebuild institutions through physical reconstruction and scientist training. In contrast, the maize TDT in Mali was undertaken by an existing, well-functioning organization (CMDT).

The effect of including additional outputs in the ROR calculation is depicted in figure 1. As above, the areas E and F could represent the benefits of these additional outputs. These areas could be the premium placed on improving food security, or augmented impacts on household income because an enriched institution is more effective at generating and transferring improved techniques. The cowpea assessments in Senegal and Cameroon estimate the benefits of early-season consumption for household

TABLE 2. COMPONENTS OF TDT BY STUDY.

STUDY	RESEARCH COSTS	EXTENSION COSTS	OTHER COSTS	OTHER OUTPUTS
Kenya	YES	NO	NO	NO
Niger	YES	YES	YES[a]	YES[b]
Senegal	YES	YES	YES[a,c]	YES[d]
Cameroon	YES	YES	NO	YES[d]
Zambia	YES	YES	YES[a]	YES[b]
Mali	YES	YES	YES[a]	NO
Uganda	YES	YES	NO	YES

[a] Costs of providing farm-level inputs.
[b] Institution building.
[c] Costs of degree training.
[d] Sensitivity analysis included food security.

food security, and include these benefits in a sensitivity analysis (see box on food security). In contrast, it is extremely difficult to estimate the monetary value of enhanced institutional capacity. Consequently, the ROR studies in Niger and Zambia discuss institution-building as an output, and appropriately include expenditures on this activity as a cost, but do not include a quantitative measure of benefits in the ROR calculation. TDT activities may also benefit consumers by lowering food prices. These benefits are not always captured in the ROR studies summarized above.

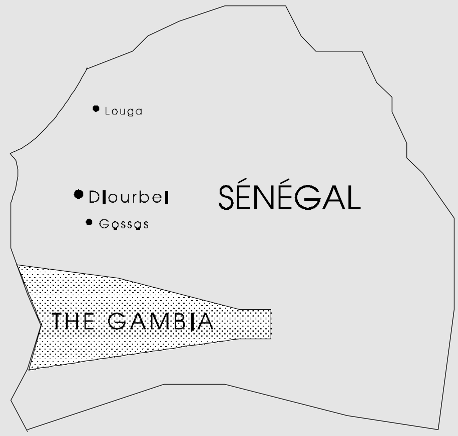
Technology development and transfer activities may benefit consumers by lowering food prices. These benefits are not always captured in the calculated rates of return.

A comparison of the Mali and Niger studies illustrates many of the differences that distinguish the individual studies. The maize TDT activity evaluated in Mali built on many past successes. Because of this history, Mali was able to use varieties developed from IITA and agronomic recommendations adapted from other national research systems. Mali was also able to benefit from the experience of the CMDT in input distribution and extension: the CMDT provides timely distribution of seed, fertilizer and agronomic recommendations. The farmers in the CMDT region of Mali have already mechanized and use chemical fertilizer in the production of cotton, so they are more familiar with improved farming techniques. Finally, the output market system in Mali is superior, with CMDT providing a leadership role. In contrast, the agroclimatic conditions in Niger are so severe that maize is not a viable crop. Moreover, international and national organizations have had relatively limited success in developing crop varieties for the low rainfall conditions in Niger. This means that the Nigerien research system had to do a great deal of institution building, and benefits from networking less than many other NARS. The Nigerien seed multiplication system cannot produce hybrid seed of adequate quality, restricting breeding activities and reducing adoption of improved varieties, and with the exception of cowpea markets in Nigeria, output markets are scarce.

2.5 Factors Influencing Impact

An important part of the impact assessment story is the analysis of factors that had a positive or negative effect on the impact of TDT. Insights from this analysis help suggest how future TDT

Food Security: An Example from Senegal.



In 1985 and 1986, "Operation Cowpea" provided research-based famine relief in the Louga, Gossas, and Diourbel regions of Senegal. Severe drought in the previous three years had decimated peanut seed supplies. Ongoing research identified short-cycle, drought-resistant cowpea varieties, complementary inputs, and agronomic practices. Operation Cowpea distributed inputs and transferred techniques through the Senegalese extension service. Schwartz et al. estimated the rate of return to this set of research, extension and input distribution activities to be 31 percent. An unanticipated benefit of the short-cycle cowpea variety was that it provided food during the hungry season before the traditional harvest of long-cycle peanut, millet or sorghum (the hungry season occurs even in normal rainfall years). Placing a premium on food available during this hungry season raised the estimated ROR to 92 percent.

programs could be better designed or implemented. Five major factors emerged from the studies presented and comments by symposium participants: agroclimatic conditions, civil unrest, research system performance, policy, and markets.

2.5.1 Agroclimatic Conditions

Many of the TDT programs evaluated in the impact studies were implemented in zones with difficult agroclimatic conditions. The Niger and Cameroon TDT programs faced challenges in trying to develop improved cereal and cowpea technology for areas with low and variable rainfall. Recent droughts in Niger also reduced impact. A diversity of agroclimatic conditions within the zone targeted by research also presents problems because of the drop in performance of an improved technology outside the conditions for which it was designed. The Zambia maize study showed, for example, that two-thirds of farmers in the best maize zone had adopted improved hybrids or varieties, but only one-third of farmers in the less favorable (low-rainfall) zone had adopted. Also, adopting farmers in the best maize zone planted three-quarters of their land in improved maize, compared to one-quarter in the low-rainfall zone.

Factors influencing the impact of technology development and transfer included agroclimatic conditions, political instability, research system performance, policies, and market efficiency.

2.5.2 Civil Unrest

Research organizations, and other institutions needed for effective TDT, depend on a stable political environment. The Uganda study illustrates the magnitude of the constraints posed by destruction of the institutional framework resulting from civil unrest. To date, African TDT activities have had to function in adverse conditions.

2.5.3 Research System Performance

Appropriate priorities, scientific leadership, favorable incentives, and adequate human and financial resources are needed if research systems are to be effective in generating improved technology. A combination of well-funded NARS, IARCs, and donor efforts in many of the countries studied (e.g., Zambia, Kenya, Cameroon) did result in the release of improved technology that was adopted by farmers. Maintaining productive research system performance with tighter budgets and reduced donor involvement requires rigorous, cost-effective, priority setting (maintaining adequate funding for fewer programs) and changes in the incentive structure (salary, researcher evaluation procedures) within NARS.

2.5.4 Policies

Policies affecting the supply and price of agricultural inputs, and the market for and price of agricultural outputs, clearly have effects on the impacts of improved technology. The Zambia study illustrates this most dramatically, showing (in some respects) an example of policy stimulating a degree of adoption of improved maize that goes beyond the limits suggested by comparative advantage. Ahmed et al. show that adoption of improved sorghum in Sudan suffered a set-back when government pricing policy changed adversely.

2.5.5 Markets

Frequently, input supplies (including seed and credit) and output markets play key roles in supporting or restraining adoption of productivity-increasing agricultural technology. Lack of effective, improved-seed multiplication and distribution was a critical constraint in Uganda and Niger, as was lack of fertilizer in Zambia. Limited output markets were constraints in Mali and Uganda. In contrast, wide use of improved maize hybrids in Zambia was encouraged by relatively effective input and output markets.

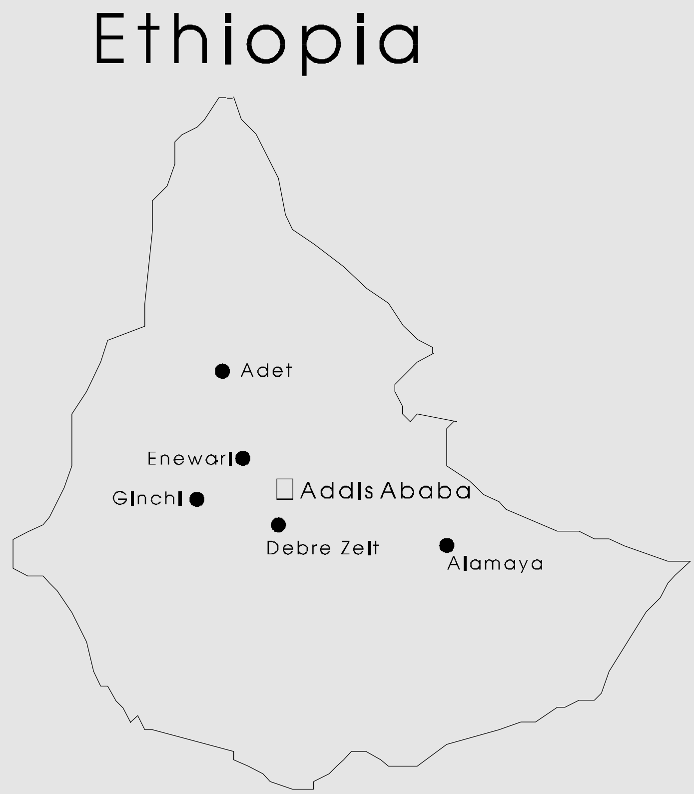
2.6 Evidence of Impact on Income and Productivity

Aggregate measures of output or productivity often hide the impacts of TDT in preventing output loss.

Some of the impact assessments provide measures of other people-level impacts such as changes in income. For example, improved rice varieties developed by WARDA showed enhanced resistance to biotic and abiotic stresses found in mangrove swamp ecosystems, and yield increases of 25-32 percent. Studies in Guinea and Sierra Leone found that these improvements led to aggregate increases in 1990 farm household incomes of US$ 0.4 million in Guinea and US$ 14 million in Sierra Leone. As adoption levels increase, it is projected that these annual increases in income will rise (Adesina and Zinnah).

Impacts have also been achieved in the livestock sector. For example, Nyaribo-Roberts estimated that the development of a dual-purpose goat (milk and meat) increased the income of adopting Kenyan farmers by as much as 60 percent. In Ethiopia, the complementarities between livestock and crops were used to develop new plowing and crop and water management techniques. The new techniques increased gross returns to farming and to farm labor by over 300 percent each (see box on complementarities between crops and livestock). While these studies do not yet compare the benefits to farmers with the costs of the TDT, certainly the impact on farmers is impressive.

Complementarities Between Crops and Livestock: A Case Study in Ethiopia.



The Joint Vertisol Project in Ethiopia addressed agricultural problems on dark clay soils (vertisols) by networking national and international institutions (Addis Ababa University, the Institute of Agricultural Research, Alemaya University of Agriculture, the Land Use Planning and Regulatory Department, ILCA, ICRISAT, AFRC Engineering, and IBSRAM). Vertisols are characterized by water logging, which diminishes agricultural productivity. Improved management practices, particularly drainage and consequent modification of cropping systems, can ameliorate the problem. Preparing adequate drainage is very demanding work and is traditionally left to the women. The major objective of the Joint Vertisol Project was to identify management techniques and innovations accessible to the farm household.

The traditional Ethiopian plow (maresha) was modified so that it could create a broad planting bed that drained well. The modified plow requires animal traction, which substitutes for household labor, particularly that of women and children. In the earliest studies, broad-bed planting was associated with yield increases of 330 percent for faba beans, and 130 percent for wheat. Farmer yields in mid-altitude areas averaged 1.5 mt/ha for wheat grain and 3.4 mt/ha for straw from 1988-1990, reflecting a doubling and quadrupling, respectively, over yields using traditional techniques. The increase in straw yield is especially important, since straw is the primary feed for the animals pulling the modified plow. The index of output per day of labor increased by more than 100 percent.

The increase in productivity generated average increases in gross margins (value of output less annual costs) to farming of 25 to 64 percent. At one site, the increases were larger, with the gross return per hectare increasing from 127 Eth. Birr (EB) to 432 EB, and the returns to labor increasing from 91 EB to 326 EB per ha. per person (2.07 EB = US $1.00). In high-altitude areas, returns to labor increased by 9.1 EB per adult per day.

Aggregate measures of output or productivity often hide impacts of TDT in preventing output loss. For example, increasing desertification may have reduced agricultural productivity in some areas of Africa by 25 percent or more. In the face of these problems, constant aggregate measures of output or productivity are indications of success. Gilbert et al. argue that research on maize has incorporated tolerance to selected pests and diseases, and has provided new approaches for maintaining soil fertility. To quantify the benefits of these accomplishments, Gilbert et al. assume that yields would have declined by 1 percent per year without the TDT. The prevention of the negative occurrences increased maize output by nearly 10 million tonnes in 1988. This translates into a 1.3 percent increase in gross agricultural product, relative to what would have happened in the absence of research. This prevention of a decline in gross agricultural product would not be noticed by comparing 1988 output to historical levels.

3. CONTINUED PROGRESS IN TDT

Over the past five years, substantial progress has been made in developing improved techniques for transfer to farmers and other participants in the food system.

Progress has been made in moving forward with the process of TDT, in spite of the adverse conditions noted above. This progress includes enhancing the capabilities of national, regional and international institutions to generate new techniques, pushing forward the technology frontier, transferring technology, and increasing productivity both in farm production and post-harvest activities. While progress does not generate immediate impact, it is an auspicious omen for future impact (see box on Maize).

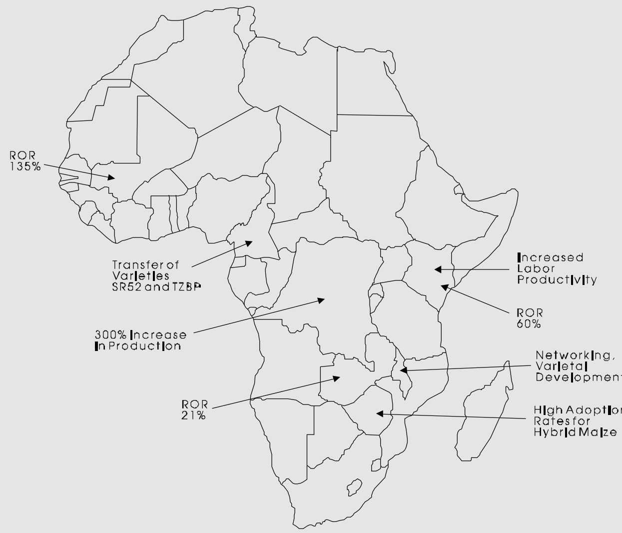
Activities such as structural adjustment, improvements in agricultural and macroeconomic policy, greater reliance on democracy and capitalism, investments in infrastructure, and a greater willingness to work with the private sector have increased the potential for TDT to have significant impact. Examples throughout the continent show how improved linkages between NARS and IARCs have led to increasing use of IARC germplasm in varieties released by national agencies. Examples in Sudan and Zambia show how public and parastatal multiplication of seed can lead to improved access to this input.

3.1 Strengthening Research Manpower and Institutions

Since independence, many African countries have significantly reorganized or reconstructed their national research systems. In young or expanding research organizations, investments in physical infrastructure and human capital are often undertaken concurrently, as the first step in re-establishing the organization (see box on Uganda). It is only in recent years that some NARS have been able to pursue aggressively their post-independence TDT targets.

From Progress to Impact: Case Studies in Maize.

The first step in the TDT process was networking of national and international research organizations to create the capacity to generate new techniques. For example, networking between the Malawi Agricultural Research Service and CIMMYT led to the creation of two new maize hybrids, which have performed well even during the 1992 drought. These hybrids are crosses between previously available Malawian varieties and a CIMMYT population. Throughout Africa, 30 to 50 percent of maize grown has been improved with germplasm from IARCs.



Following the development of new techniques, they are transferred to the farmers. Early examples of transfers include the release of varieties such as H611 in Kenya, and SR52 in Zimbabwe; recent releases developed (at least partially) by AID-sponsored projects include the Malawian releases MH17 and MH18, the Shaba variety from Zaire, and many other varieties. AID has also helped transfer existing varieties across national and regional boundaries, as exemplified by recent efforts introducing SR52 from Zimbabwe and TZBP from Nigeria into the Amadou plateau and the Benoue regions of Cameroon.

The transfer is complete when farmers adopt the new varieties. In Kenya and Zimbabwe, over 60 percent of the farmers in some areas are growing improved varieties or hybrids. However, in some countries lack of adoption is perhaps the biggest constraint in achieving impact.

Adoption of new varieties leads to increases in maize output, as seen by the average increase in production of 2.6 percent over the past 25 years. Adoption also leads to increases in productivity, as indicated by average annual yield increases in sub-Saharan Africa of 0.74 percent over the past twenty years. Output and yield increases are more impressive in areas with greater adoption, such as the 300 percent increase in local production associated with TDT activities in the North Shaba province, Zaire.

The farm household benefits from increased agricultural productivity. Studies of returns to maize research in Kenya, Mali and Zambia found that the tangible benefits to farm households clearly overshadowed the costs of the TDT.

Concurrent with generating benefits for the farm household, one observes increased transfer of resources and outputs between the agriculture and non-agricultural sectors. For example, in the cotton-growing regions of Mali, maize has been transformed from a subsistence crop into a cash crop, generating income for which the farmer can make investments, or purchase of agricultural inputs or non-agricultural consumer goods.

Uganda: From Reconstruction to Impact

In Uganda, the breakup of the East African Community and arbitrary macro policies of the 1970's, compounded by war and civil unrest in the early 1980's, resulted in severe disruption of the agricultural research system. Facilities were damaged and equipment looted, seed lines for breeding were lost, varietal trial results were obliterated, and scientists were displaced. In 1986, after the end of the civil war, USAID began investments in rebuilding the Ugandan research system, following a 1984 agreement to strengthen Ugandan capacity for teaching and research. Under the Manpower for Agricultural Development (MFAD) project, implemented by The Ohio State University, efforts were concentrated on rebuilding the capacity for food crop research at Namulonge research station. Two other experiment stations, the Makerere University Faculty of Agriculture building, and the University farm were rehabilitated. The MFAD project also brought in technical consultants, supported short and long-term training of research personnel, supported improved teaching, and helped to establish an M.Sc. program in Agricultural Economics.

Reconstruction of the national research system continued with the provision of funds to strengthen commodity research programs. In 1987, the maize program was reinstituted with an effort to reassemble a stock of maize germplasm for varietal breeding and selection. Collection of local varieties, and borrowing from other national programs, CIMMYT and IITA were successful in replenishing the germplasm. Varietal testing started in 1988 and new crosses were created in 1989. The first new variety, Longe 1, was released in September, 1991, and is undergoing multiplication for distribution to farmers. Additional varieties with further improvements are expected to be released in 1994.

The sunflower program was launched in 1988, with varietal trials of imported hybrids. During 1989 and 1990, progeny selection, multi-locational on-station trials and on-farm trials were undertaken. This resulted in the release and distribution to farmers of a Sunfola variety in 1991. Working in conjunction with the breeding program, a separate USAID project (implemented by in International Living) is promoting the development and adoption of appropriate technology for village-level pressing of oilseeds. This program has helped to generate demand for the Sunfola variety, which has a greater oil content and is easier to process than traditional varieties. It also made a major contribution toward distribution of improved seed to farmers: over 11 percent of 1992 sunflower production was Sunfola.

The soybean research program was revitalized in 1988 with a multi-locational screening program. The variety ICAL-131 was given partial release in 1989 under the name Nam 1, and after two years of further trials was fully released in 1991. Ongoing varietal trials have identified another variety, proposed for release in Fall, 1992.

This story of progress towards impact is encouraging. However, Ugandan agriculture still faces an uphill battle. The continued progress of the research system is jeopardized by low operating funds and by salaries so low that they provide less than one-half of average household food expenditure. Impacts of varietal breeding are limited by inadequate seed multiplication capacity, particularly for hybrids, and by substandard extension services. Macroeconomic shocks such as changes in the international coffee price (Uganda's major export) and the lack of satisfactory output markets aggravate the problems. Current efforts to address these problems include structural adjustment measures, the creation of an independent National Agricultural Research Organization, and rehabilitation of the seed multiplication scheme.

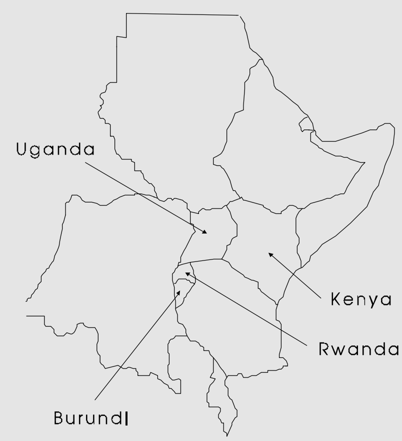
Networking among national, regional and international organizations is an important component of enhanced research efficiency. As the Ugandan example shows, networking can help to replicate information and replace breeding lines lost during war, or other cataclysmic events. Another example is Cameroon, which in collaboration with the Semi-Arid Food Grain Research and Development (SAFGRAD) activity was able to start on-farm testing of a new cowpea variety in 1980, one year after the inception of the cowpea research program. Identification by the Bean/Cowpea CRSP of a high-yielding variety was possible because of information available from IITA regional screening trials. However, no evidence was presented on what makes some networks effective and others ineffective.

3.2 Pushing Out the Technology Frontier

Over the past five years, substantial progress has been made in developing improved techniques for transfer to farmers and other participants in the food system.

An essential part of the TDT process is the development of improved techniques for transfer to farmers and other participants in the food system. Over the past five years, substantial progress has been made in developing such techniques. ICRISAT has been involved in the release of 42 improved sorghum varieties and 23 improved millet varieties (ICRISAT). IITA has used a network approach to coordinate national research programs via SAFGRAD maize and cowpea programs. For example, SAFGRAD contributed to the release of 30 improved maize varieties and 24 improved cowpea varieties. ICRAF and the Burundi, Kenya, Rwanda and Uganda NARS initiated the Agroforestry Research network for the highlands of East and Central Africa in 1986 (Hoekstra). This network has developed and released 7 new techniques for East Africa, including 2 dealing with soil fertility and 4 with soil conservation (see box on hedgerow cropping). WARDA's work in mangrove swamp ecosystems shows that improved rice varieties outyield the best local varieties by 25 to 32 percent (Adesina and Zinnah). CIAT networking (Kirkby et al.) led to the development and release since 1986 of over 25 new varieties in 9 countries, including some countries that had never previously released an improved bean variety. An impact study of the variety Umubano, introduced into southern Rwanda from the CIAT germplasm bank in 1987, is now being grown by 70,000 farmers on 10,800 hectares. The positive effects of CIP efforts and the negative effects of blight on traditional varieties contributed to a nearly complete replacement of East African potato varieties over the past ten years. CIP estimates that the ROR to potato research and production and extension in Burundi, Rwanda and Zaire is 91 percent.

Hedgerow Cropping: A Case Study in East Africa.



"Continuous cropping and erosion of top soil have greatly contributed to the depletion of nutrients and subsequent decline in crop yields in most land use systems in the highlands of East and Central Africa. Maize yields on such depleted soils are well below 1 ton per hectare, ... while yields on newly opened fields may reach 4 to 5 tonnes per hectare (Hoekstra, p. 2)." To address these problems, hedgerow intercropping was assessed in on-station trials. In Uganda, soil run-off was reduced by 58 percent and water run-off was reduced by 20 percent. In Uganda and Rwanda, the hedges also created a visible build-up of soil above the hedge. The hedgerow technique generates increases in maize yields of 45 percent on acid soils in Burundi and 760 kg/ha per season in western Kenya. The successful on-station trials led to on-farm testing with 52 farmers in western Kenya. Yield and soil fertility effects are currently being assessed.

4. LOOKING TO THE FUTURE

This section presents ideas on maintaining a flow of improved techniques, translating improved techniques into impact, and monitoring and evaluating these impacts.

4.1 Continued Investment in Agricultural TDT

USAID may want to maintain or gradually increase the real funding for agricultural TDT in sub-Saharan Africa.

Given the importance of raising productivity in agriculture as a step towards agricultural transformation, continued investment in agricultural TDT is merited. The evidence of impact achieved from previous investments shows that those investments have paid off.

Coupled with the evidence of beneficial changes in the macroeconomic policy environment in many countries, this provides the basis for expecting that future investments will pay off. Consequently, USAID may want to rethink its strategy of investment in African development, and maintain or gradually increase the real funding for agricultural TDT in sub-Saharan Africa.

4.2 Improving the Effectiveness of TDT

Despite the conclusion that previous investments in TDT have had meaningful impacts, these investments have not always been used to maximum effectiveness. Three issues are important in improving effectiveness over the next five to twenty-five years.

4.2.1 Prioritizing the Scope and Scale of TDT Activities

A research system is an international partnership that includes NARS, IARCs, CRSPs, NGOs, universities, private sector organizations, and other participants in the TDT process.

Consideration should be given to division of labor among research institutes within a given region, in order to realize economies of scale on key research topics. Given the current budget situation and continued pressure in the near future, national organizations may wish to focus the majority of their efforts on a small number of the most important crops, animals, or productivity constraints, and rely on networks for the bulk of improvements in secondary commodities (while maintaining enough involvement to take advantage of the networks). The decision to focus on a small number of crops will be most effective if it is made proactively by the NARS, rather than imposed by external organizations or donors.

At the same time that national organizations are focussing on a smaller number of primary commodities, the scope of TDT activities for each commodity may be diversified to include post-harvest activities. Many research organizations are currently moving in this direction. Diversification into post-harvest TDT activities improves effectiveness in two ways: first, it increases the number of consumers and/or the size of the benefits to consumers by providing agricultural products that are tailored to specific consumer needs. Second, in some cases it may allow for greater complementarity between national and international organizations. For example, if international organizations are providing a steady flow of improved germplasm or varieties, then national organizations may be able to focus on storage, transport from food surplus areas to food deficit areas, or other post-harvest activities that increase the value-added in the food sector.

Prioritizing the scope and scale of TDT activities, financial sustainability, and agricultural sustainability can improve the effectiveness of TDT activities. What is perhaps unique about the symposium is the movement towards a commodity sector perspective as the next logical step toward including more demand-side considerations in its TDT agenda.

4.2.2 Financial Sustainability

> **Organizations should look to the long-term health of their base of human capital by limiting scientist attrition and replacing those who take other jobs, and by enhancing their ability to generate impact in the face of changing social, economic and policy environments.**

Sustainability is a broad issue to be addressed by research organizations and networks. In the current fiscal environment, financial sustainability is a major consideration. Public organizations must consider whether the funding sources will continue to be adequate over the next 2-3 decades, and what impacts the organization must demonstrate in order to maintain or increase their allocations from these sources. They may also examine alternative funding mechanisms, such as collaboration with the private sector, producer or consumer taxes, and user fees or service charges. Organizations may also wish to examine cost-cutting measures that enhance rather than hamper the effectiveness of the TDT activities. Achieving such objectives may require increased salaries, improved operating and travel budgets, expanded socio-economic units, and other expenditures. At the same time, young organizations and networks need to establish a track record and tradition of impact so that they become a permanent feature of African agricultural research.

4.2.3. Agricultural Sustainability

Sustainability also refers to the agricultural system in which the TDT organizations operate. While it is imperative to develop improved agricultural technology, it is often a poor tradeoff to achieve immediate impact at the expense of the natural resource base. Assessments of potential TDT activities should examine not just the potential pecuniary impacts, but also the impacts on the social structure, environment, and other national goals and priorities.

4.3 Improving the Measurement of Impact.

Research and other TDT organizations are being asked to demonstrate impact on people and progress in the development of less-developed economies. This represents a fundamental change from the accountability questions asked during the 1980s. It requires a more detailed examination of what happens to improved techniques after they leave the research station. People-level impacts, whether summarized in an economic rate of return calculation, or in terms of income or other indicators, cannot be evaluated without information about the extent (number of users) and degree (intensity of use) of adoption of improved techniques, and the effect of these techniques on production costs and outputs. ROR calculations are typically quite sensitive to assumptions about adoption. For crop or livestock variety research, it is important to collect information on adoption by variety, since otherwise it may be impossible to distinguish the spread and impact of the new improved variety from previously released improved varieties. Similarly, data on agronomic practices are important in measuring the impact of agronomic TDT. Care must also be taken in determining the net impact of TDT on productivity trends, over and above any changes that would have occurred without the TDT investments being evaluated.

People-level impacts cannot be evaluated without information about the extent and degree of adoption of improved techniques and the effect of these techniques on production.

To monitor impact, it is useful to adopt a commodity sector perspective, since the constraints or leverage points that affect impact may be found beyond the farm level, in marketing, processing, or consumer demand. If improved productivity in the commodity sector is the goal, the highest priority research might best be focused not on raising farm production, but on improving the marketing and processing of that output to better satisfy consumer preferences, or on modifying the types of crops or livestock raised by farmers in accordance with expressed consumer demand.

4.4 Moving Forward

Despite the findings of impact under adverse conditions and the recent improvement in conditions, TDT in sub-Saharan Africa does not have clear sailing ahead. A number of issues, both internal and external to the TDT organization, were brought out in the symposium. Many of these issues, such as low salaries and consequent high turnover among scientists, have been discussed in other symposia and, in principle, have simple solutions.

What is perhaps unique about the symposium is the movement towards a commodity sector approach as the next logical step toward including more demand-side considerations in the TDT agenda.

What is perhaps unique about the symposium is the movement towards a commodity sector approach as the next logical step toward including more demand-side considerations in the TDT agenda. Demand-side considerations reflect those characteristics of agricultural techniques and products that are of greatest importance to the individual adopters of techniques and consumers of products. Farming systems research (FSR) and farmer-oriented approaches were designed to help determine what farmers want as adopters of improved techniques. The commodity systems approach incorporates demand-side considerations from consumers of agricultural products. It complements the farm-level approach by examining what happens to the agricultural products as they leave the farm. It provides a guide to what product characteristics are valuable to processors, distributors and the final consumers. As the agricultural sector undergoes transformation and the economy becomes more reliant on markets to deliver agricultural products to a growing number of off-farm consumers, the commodity sector approach becomes increasingly important as a tool to maintain the link between consumer demand and farm production.

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ANNEX 1. LIST OF REGISTRANTS

Lawrence Abel	USAID R&D/EID/RAD
Akinwumi Adesina	WARDA
Margie Aimery	MSU
Muso Akapelwa	Howard Univ.
Frank Alejandro	USAID/R&D/POL
Elizabeth Allred	NASULGC
Pat Barnes-McConnell	Bean/Cowpea CRSP-MSU
Rick Bennett	
Robert Bertram	USAID R&D/AGR/IARC
Richard Bernsten	MSU
Hailu Beyene	Ethiopia
Ouendeba Botorou	INRAN, Niger
Duncan Boughton	MSU
Lukas Brader	IITA/Nigeria
Douglas Brown	USAID
Kenneth Brown	CIP
Ans Burgett	USAID
Derek Byerlee	CIMMYT
Cheryl Christensen	USDA/ERS
Gary Cohen	USAID AFR/ARTS/FARA
Eric Crawford	MSU
David G. Cummins	Univ. of Georgia
Ralph Cummings	USAID R&D/AGR/IARC
Dana Dalrymple	USAID R&D/AGR/IARC
Ron Daniel	USAID AFR/SWA
John Day	USDA/ERS/RID

Arthur Dommen	USDA/ERS/RID
Daniel Dworkin	USAID AFR/ARTS/FARA
Georges Dimithe	MSU
Howard Elliott	ISNAR
Mark Erbaugh	Ohio State Univ
Michael Fuchs-Carsch	USAID AFR/ARTS/FARA
Vasant Gandhi	IFPRI
George Gardner	USAID AFR/ARTS/FARA
Mathurin Gbetibouo	The World Bank
Elon Gilbert	Consultant
Robert Gurevich	SANREM CRSP
Virginia Hammell	NASULGC
David Hansen	Ohio State Univ.
Roger Hanson	North Carolina State Univ.
Bill Hargrove	USAID AFR/ARTS/FARA
Thomas Herlehy	USAID AFR/ARTS/FARA
John Hicks	USAID DAA/AFR
Jeff Hill	USAID AFR/ARTS/FARA
Peter Hobby	USAID AFR/ARTS/FARA (AMEX Int'l.)
Dirk Hoekstra	ICRAF
Jane Hopkins	IFPRI
Harry Hortik	USAID R&D/AGR/AP
Alan Hurdus	USAID R&D/AGR
Pat Isman	USAID/R&D/EID
Dr. Jalloh	SPAAR

Valentine James	USAID R&D/UC
Wm. Frederick Johnson	USAID BIFADEC/UC
T. David Johnston	USAID R&D/EID
Ann Judd	Economic Growth Center, Yale Univ.
Roger Kirkby	CIAT
Earl Kissenger III	USAID AFR/ONI
Walter Knausenberger	USAID AFR/ARTS/FARA
Shubh Kumar	IFPRI
Bernard Kupfuma	MSU
Martin Kyomo	SACCAR - Botswana
Hiram Larew	USAID
Jeffrey Lee	USAID
Carolle Levin	USAID
Rita Laker-Ojok	MSU
Melanee Lowdermilk	USAID AFR/ARTS/FARA
Ken Lyvers	USAID R&D/AGR
Don McClelland	USAID
Mike McGahuey	USAID AFR/ARTS/FARA
David Makanda	MSU
Valentina Mazzucato	MSU
Wendell Morse	USAID R&D/UC
Millie Morton	USAID AFR/ARTS/FARA
Dr. Mugerwa	Makerere University, Uganda
Dr. Mukiibi	Ministry of Agriculture, Uganda
Watson Mwale	Ministry of Agriculture, Zambia
Lewis Myghogho	ICRISAT

Mohamed Noor	
Fanny Nyaribo-Roberts	WINROCK International
James Oehmke	MSU
Dr. Okedi	Uganda
Dr. Pachico	CIAT
Chandra Pattanayak	The World Bank
Peter Pee	SPAAR
Timothy Phillips	Texas A&M
Shirley Pryor	USAID
Harry Rea	USAID R&D/AGR
Curt Reintsma	USAID AFR/ARTS/FARA
Charles Renard	ICRISAT
Glenn Rogers	USAID REDSO/WCA
Jose Luis Rueda	CIP
Joseph Rusike	MSU
James Ryan	ICRISAT
John Sanders	Purdue Univ.
Marie-Therese Sarch	
Ahmedoul Bashir Sarr	Texas A&M
David Schroeder	USAID R&D/AGR
Mary Schulz	MSU
Shahla Shapouri	USDA/ERS
Emmy Simmons	USAID
Charles Sloger	USAID R&D/AGR
Darl Snyder	Univ. of Georgia
Solibo Some	SANREM CRSP

M.S. Sompo-Cessay	Mali-INSAH
Louise Sperling	CIAT
John Staatz	MSU
Gloria Steele	USAID R&D/EID/RAD
John Steele	USAID AFR/ARTS/FARA
James Sterns	MSU
Ben Stoner	USAID AFR/ARTS/FARA
Moussa D. Traore	Mali - Inst. of Rural Economy
Tshikala Tshibaka	IFPRI
Corrine Valdivia	Univ. of Missouri
Ralph von Kauethawn	ILCA
John Walsh	ILCA
William Phillip Warren	USAID R&D/AGR/AP
Mike Weber	MSU
Jerry Wolgin	USAID AFR/ARTS
John Yohe	INTSORMIL

ANNEX 2. LIST OF PAPERS PRESENTED

"The Future of A.I.D. Investment in Agricultural Research," Richard Bissell, AA/R&D, Jerry Wolgin, AFR/ARTS.

"A Retrospective View of A.I.D. Investment in Agricultural Research in Sub-Saharan Africa," Cheryl Christensen, USDA/ERS

"What is Agricultural Transformation?", John Staatz, MSU

"Maize Research in Africa: The Obscured Revolution", Elon Gilbert

"Actual and Potential Impacts of Available Maize Technology", Derek Byerlee, CIMMYT

"Impacts of Mangrove Swamp Rice Research", Akin Adesina, WARDA

"Technology, Impact and Agricultural Transformation: Lessons Learned from Impact Studies", Jim Oehmke, MSU.

"Evidence on the Impact of Research on Regional Productivity", Ann Judd, Yale University.

"Cereal Grains in Niger", Valentina Mazzucato.

"The Ecosystem Approach to Improving Research Programming", Roger Hanson, Tropsoils CRSP.

"Cowpea in Cameroon", James Sterns, MSU.

"Maize in Mali", Duncan Boughton, MSU.

"The Impact of Kenyan Wheat Research", David Makanda.

"The Impact of USAID-Supported Research on Maize and Oilseeds in Uganda, 1986-2006.", Rita Laker-Ojok.

"The Impact of Hageen-Dura I in Sudan", Mohammed Ahmed and John Sanders, INTSORMIL.

"Zambia Impact Study", Eric Crawford, MSU.

"USAID/Africa Bureau Draft Strategic Framework for Technology Development and Transfer," Jeff Hill, AFR/ARTS/FARA.

"The Subsector Approach: Assistance with Impact Assessment," Richard Bernsten, MSU.

"Institution Building and Institutionalizing Impact Assessment," John Yohe, INTSORMIL.

"Improving Research Design Through Social Science Evaluation," Fanny N. Roberts, Winrock International.

"Institutionalizing planning, monitoring, and evaluation to serve NARS' needs", Howard Elliott, ISNAR.

"Impact of Structural Adjustment on Technology Adoption: Implications for Research Design," Aruther Dommen, USDA/ERS.

"ICRISAT's Research and Agricultural Transformation in Africa", Charles Renard.

"Assessment of Results from Three Collaborative Research Networks in Sub-Saharan Africa", Lukas Brader.

"A Rapid Impact Assessment of Vertisol Technology", John Walsh.

"The Agroforestry Research Network for the Highlands of East and Central Africa", Dirk Hoekstra.

"Impact of the Eastern Africa Bean Research Network on Research Priorities, National Research and Farmers", R. A. Kirkby, C.S. Wortmann, H.E. Gridley, CIAT.

"The PRAPACE Network: CIP-NARS Collaboration for Sustainable Agricultural Production in Africa," Jose Luis Rueda, CIP.

ANNEX 3. REFERENCES FOR ROR STUDIES OF AFRICAN AGRICULTURAL TDT

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LIST OF ACRONYMS

Institutions

AFR	Africa Bureau (USAID)
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CMDT	Compagnie Malienne Pour le Développment Des Textiles
CRSP	Collaborative Research Support Program
IARC	International Agricultural Research Center
ICRAF	International Center for Research on Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute for Tropical Agriculture
ILCA	International Livestock Centre for Africa
MFAD	Manpower for Agricultural Development
NARS	National Agricultural Research Service
NGO	Non-Governmental Organization
OICD	Office for International Cooperation and Development (USDA)
RD	Research and Development (USAID)
SAFGRAD	Semi-Arid Food Grain Research and Development
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WARDA	West Africa Rice Development Authority

Other

EB	Ethiopian Birr
FSR	Farming Systems Research
MARIA	Maize Research in Africa
ROR	Rate of Return
TDT	Technology Development and Transfer

ENDNOTES

1. "Symposium on the Impact of Technology on Agricultural Transformation in Africa," held at the Ramada Renaissance Techworld Hotel, Washington, D.C., October 14-16, 1992. The Symposium was organized by the Department of Agricultural Economics, Michigan State University, and by AID (AFR/ARTS/FARA and R&D/EID/RAD), and funded under the MSU Food Security in Africa Cooperative Agreement, DAN 1190-1-00-4090-00 and the MSU Food Security II Cooperative Agreement, AEP-5459-A-00-2041-00.

2. The authors are Associate Professor and Professor, respectively, in the Department of Agricultural Economics, Michigan State University.

3. This also eliminates the need to determine what portion of IARC expenditures should be included as costs incurred in support of particular national programs.