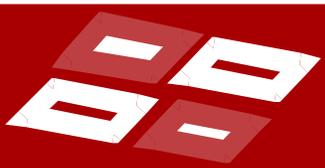


SD Publication Series

*Office of Sustainable Development
Bureau for Africa*

**Agricultural Technology Development
and Transfer in Africa**

Impacts Achieved and Lessons Learned



James F. Oehmke

Michigan State University

P. Anandajayasekeram

Southern Africa Center for Cooperation in Agricultural Research and Training

William A. Masters

Purdue University



Technical Paper No. 77

November 1997



***Productive Sector Growth and Environment Division
Office of Sustainable Development
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Foreword

Since Congress established the Development Fund for Africa (DFA) in 1987, the U.S. Agency for International Development (USAID) has been challenged to scrutinize the effectiveness and impact of its projects in Africa and make needed adjustments to improve its development assistance programs. At the same time, structural adjustment reforms have been adopted by many sub-Saharan African countries with some progress in market liberalization.

As donor agencies face severe cutbacks and restructuring, and less assistance becomes available to developing countries (not just in sub-Saharan Africa), new ways must be found to channel declining resources to their most effective and productive uses. The USAID Africa Bureau's Office of Sustainable Development, Productive Sector Growth and Environment Division (AFR/SD/PSGE) has been analyzing the Agency's approach to the agricultural sector in light of the DFA and the experience of recent policy reform programs in sub-Saharan African countries.

Improving the quantity, quality and range of technology available and used can provide an opportunity for low-income producers and consumers to improve their real income, create private sector based jobs in providing support services for rural enterprises, and sustain the use of natural resources. This report is a synthesis of numerous studies and field work experience in building capacity in Africa to do impact studies to inform our understanding of how well the technology based activities have performed.

The Africa Bureau supported work on better understanding the impact of technology based programs was initiated in the early 1990s. The early studies completed by Michigan State University through the Food Security Program provided the foundation for USAID to better understand the impact of its past investments. Since then, much has been achieved through the efforts of INSAH and Purdue University in West Africa, SACCAR in Southern Africa, and ASARECA in East Africa in institutionalizing the concern for understanding impact and building the skills needed to conduct studies. This

work has significantly expanded the body of knowledge now available on the impact of technology systems in Africa. And, it has provided a number of useful lessons both in terms of how to get the most out of technology based programs and how to organize and conduct impact assessments.

This synthesis report underscores the point that USAID, African Government and other donor funding in technology based programs in Africa has been a wise use of scarce resources. The findings also point out that more could have been achieved through more efficient targeting of resources. In sum, much remains to be done to improve the technology systems in Africa, including building partnerships among the public and private sector to build on the advances made in liberalizing markets. In sum, the report provides useful input into the dialogue on future directions and strategic challenges for technology systems in Africa. It provides insight to better understand where we have been, where we are now, and challenges that lie ahead.

A special thanks needs to be extended to the authors of this report for their work, as a team, in reviewing the findings of the many reports and studies reflected in this report and for developing this publication. Without their joint professionalism and commitment this report could have never been completed. In addition, the many authors of individual studies, a majority of which are African, need to be acknowledged. Individually and jointly they have made a major contribution to our understanding of technology systems in Africa.

SD/PSGE believes that this report will be useful to USAID field mission and many others in Africa, providing insights, ideas and approaches to food security strategies and agricultural sector activities.

David A. Atwood, Chief
Productive Sector Growth and Environment Division
Office of Sustainable Development
Bureau for Africa
U.S. Agency for International Development

Executive Summary

Most sub-Saharan Africans depend on agriculture for their livelihood. Improving the welfare of the next generation of Africans thus requires sustainable technical change in agriculture.

Africa has neglected agriculture and agricultural technology development and transfer (TDT) over the past twenty years. Agricultural production per capita declined by 22% from 1971 to 1984, and the share of African government spending devoted to agricultural TDT declined by 37% from 1971 to 1991.

Was the decline in African agriculture due to the inherent hostility of the African environment, making the continent basically unsuitable for agriculture? This view might justify abandoning agricultural TDT, in favor of investment in other sectors. But there is overwhelming evidence that Africa's agricultural decline during the 1970s and early 1980s was not due to the continent's climate or geography, but rather to its unique demographic and political conditions—and that Africa's limited TDT efforts did have a substantial impact in limiting the damage inflicted by these problems.

This document provides a synthesis of nearly a decade of socio-economic studies, conducted by a number of scientists funded from a variety of sources, quantifying the impacts of TDT, institutionalization of impact assessment, and needed innovations in African agricultural TDT. The document follows from a roundtable discussion held in Washington D.C. in January 1997.

Despite roadblocks and neglect, the emergent picture from recent quantitative studies is one of considerable success in African agricultural TDT. Perhaps the most widely known success story is that of hybrid maize in southern Africa, beginning with SR52 released in Zimbabwe (then Southern Rhodesia) in 1960. Less well known is the continued success in recent decades of maize TDT in developing varieties for use in areas with short rainy seasons, low soil nutrient levels, and the adoption and use of these varieties throughout the continent. Cotton in

francophone West Africa, irrigated sorghum in Sudan, striga-resistant sorghum throughout much of Africa, tobacco, tea and coffee all provide examples of how TDT has been able to contribute significantly to African agricultural production.

Aggregate evidence shows that Africa's agricultural decline was dramatic, but limited to the period between 1971 and 1984. For example, after 1984 there is a sustained improvement in cereal yields in all parts of the continent: fueled primarily by yield increases, in the decade from 1984 to 1993 Sahelian grain production doubled; throughout sub-Saharan Africa grain production increased at a rate of about 3 percent per year. These changes are not an artifact of the drought in parts of Africa in 1984: they are fueled primarily by sustainable increases in yield, attributable at least in part to successful agricultural research. Decomposing recent measurements of African agricultural growth suggests that up to one-third of the growth in aggregate agricultural productivity is attributable to past investments in agricultural research. This roughly corresponds to a contribution of agricultural research to economic growth of 1/4 of a percentage point: in other words, in the absence of agricultural research African economies would have grown 1/4 point slower than they actually did.

A compilation of case studies quantifying RORs to African agricultural TDT confirms these aggregate findings. RORs to African agricultural research are similar in magnitude to those found in other parts of the developing world. Of the 27 RORs to past investments in agricultural TDT, 21 show RORs in excess of 12%. Detailed investigation into the six lower RORs suggest that researchers had not yet found the right mix of activities to produce cost-effective solutions in challenging agro-ecological environments. Examining the future potential impact of innovations recently released or still in the development stage, 24 of 30 forward-looking RORs show expected returns in excess of 12%. These are outstanding returns on investment by any criterion.

The studies do not paint an unequivocally rosy picture of African agricultural TDT. Success has often come through the painstaking work of underpaid scientists working around the system, rather than through institutional procedures that contribute to research success. Lack of prioritization, low salaries, negligible operating budgets, low staff morale and high turnover, and a host of other problems plague African TDT institutions. Institutional innovation could greatly increase the efficiency of investments in agricultural TDT.

Critical issues to be addressed by TDT institutions that can be informed by future TDT impact assessment include:

- Defining and sequencing a research agenda for resource-poor areas.
- Allocating effort between subsistence and commercial farming.
- Utilizing relationships between technical change and market development.
- Creating institutional innovations for improved TDT efficiency.
- Determining appropriate funding levels.

- Strengthening institutions to improve the mobilization and allocation of TDT resources.

- Utilizing complementarities between trade, growth, and agricultural innovation.

Several striking conclusions can be drawn from this review of the literature and follow-up discussion:

- No agricultural economy has developed in the absence of technical innovation in agriculture.

- African agricultural TDT has had impact across a variety of countries, commodities, and agro-climatic conditions.

- There is institutional failure in African national agricultural TDT systems.

- Donors and African national governments have failed to invest adequate levels of resources in agricultural TDT.

- Agricultural TDT is critical to the future of broad-based improvements in the welfare of African people.

It is now up to African governments and donors to invest according to their vision of 21st-century Africa.

Glossary of Acronyms and Abbreviations

ADP	agricultural development project
AFTAG	African Technical Advisory Group
ANR	agriculture and natural resources
ASARECA	Association for Strengthening Agricultural Research in East and Central Africa
CIMMYT	International Center for Wheat and Maize Improvement
CIRRAD	Centre de Coopération Internationale en Recherche Agronomique par le Développement
CMDT	Compagnie Malienne pour le Développement des Textiles (Malian Company for the Development of Textiles)
CRSP	Collaborative Research Support Program
DR&SS	Department of Research and Specialist Services
FANR	Food, Agriculture, and Natural Resources
FAO	Food and Agricultural Organization (United Nations)
FSII	Food Security II (USAID / MSU cooperative agreement)
FSR	farming-systems research
IA	impact assessment
IARC	International Agricultural Research Center
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institute of Rural Economy - Mali
INERA	Institut d'Etudes et de Recherches Agricoles (Institute of Studies of Agricultural Research) (Burkina Faso)
INRAN	Institut National de Recherches Agricoles du Niger (Nigerien National Institute of Agricultural Research)
INSAH	Institut du Sahel (Institute of the Sahel)
IRR	internal rate of return
ISNAR	International Service for National Agricultural Research
ISRA	Institut Senegalais de Recherches Agricoles (Senegalese Agricultural Research Institute)
KARI	Kenya Agricultural Research Institute
M&E	monitoring and evaluation
MSU	Michigan State University
NARI	national agricultural research institution
NARS	National Agricultural Research System(s)
NGO	nongovernmental organization
NRM	natural resource management

OHV	Operation Haute Valle (Mali)
R&D	research and development
RARI	regional agricultural research institutes
REDSO/ESA	Regional Economic Development Support Office / East and Southern Africa (USAID)
ROR	rate of return
SACCAR	Southern Africa Center for Cooperation in Agricultural Research and Training
SADC	Southern Africa Development Committee
SAFGRAD	Semi-Arid Food Grain Research and Development
SMIP	Sorghum and Millet Improvement Program
SPAAR	Special Program for African Agricultural Research
TDT	technology development and transfer
TFP	total factor productivity
USAID	U.S. Agency for International Development
USAID/W	U.S. Agency for International Development / Washington, D.C., headquarters
USDA	U.S. Department of Agriculture

1. Context

Most sub-Saharan Africans depend on agriculture for their livelihood. Improving the welfare of the next generation of Africans thus requires sustainable agricultural development—that is, sustained improvements in the productivity with which the human and natural resources employed in agriculture are used. Agricultural and natural resource (ANR) technology development and transfer (TDT) plays a key role in this process (Ruttan et al. 1987). Without technical innovation in agriculture, it is almost a surety that most African economies will not be able to generate the surplus needed to sustain higher rates of economic growth.

African development policy has, at times, neglected agriculture and agricultural TDT. In the colonial period, the perception was that small-scale agriculture took care of the food crops and could expand area when demand increased. Output increases would lead to price collapses due to the inelastic demand. The export crops were taken care of by special public programs and often specific institutes financed by producer taxes. As land area expansion has become more difficult, the attitude towards food crops has had to be reevaluated. Moreover, research and price incentives for export crops have often been neglected. Hence, both food crop and export sectors have frequently stagnated.

Following the independence of most African nations in the early 1960s, misplaced optimism that Africa could skip over agricultural development and proceed immediately to industrialization caused underinvestment in agriculture. Perceptions of substandard performance by investments made in the agricultural sector perpetuated this underinvestment through the 1980s and early 1990s. These perceptions resulted from some very real concerns, such as rapidly increasing agricultural imports (Figure 1.1), as well as more subjective issues such as the lack of a noticeable green revolution in Africa.

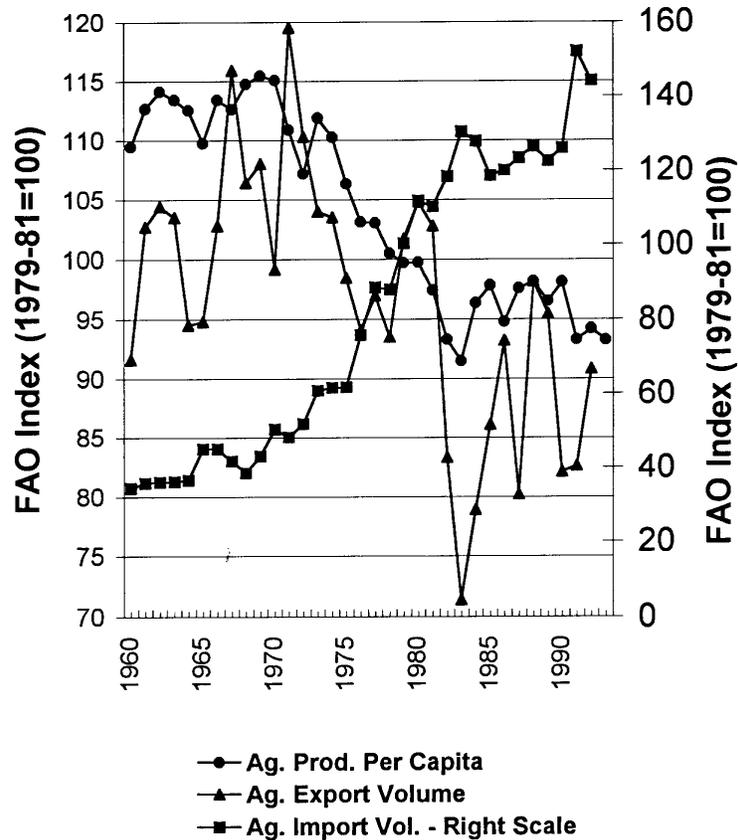
The Asian and American green revolution bypassed Africa. This was partly because Africa has a

difficult agro-ecological environment, characterized by large areas with low and variable rainfall and limited irrigation potential, and other areas with diverse agro-climates within a small geographic area. However, this was also because the continent was just emerging from colonial rule in the 1960s and because with relatively abundant land there rarely were large-scale food shortages. It was not until after the acceleration of African population growth, as well as the Sahelian droughts and world food crisis of 1973-1974, that food crops in Africa became a research priority.

With few historical guideposts, scientists working on Africa's food crops and livestock in the 1970s did not always immediately identify the most successful research strategies. Breeding and agronomic trials were often conducted in higher-rainfall areas or under irrigation. The principal response to weather risk was the search for shorter cycle cultivars, which occurred over all the semiarid regions in the 1970s and 1980s. Agronomic and varietal recommendations often failed to account for agro-ecological differences in a country, making them inappropriate for most farmers. Limited knowledge of local conditions drove a shift toward farming systems research, simply to understand farmers' practices, so that appropriate techniques could be developed.

Despite some initial roadblocks and growing pains, scientists have been able to generate advances in agricultural techniques and inputs that have made significant contributions to African agricultural productivity and production. Perhaps the most widely known success story is that of hybrid maize in Southern Africa, beginning with SR52 released in Zimbabwe (then Southern Rhodesia) in 1960. Less well known is the continued success of maize TDT in developing varieties for use in areas with short rainy seasons, low soil nutrient levels, and the adoption and use of these varieties throughout the continent (see, for example, Gilbert et al., 1994 or Byerlee and Eicher, forthcoming). Cotton in francophone

Figure 1.1. African Agricultural Production Per Capita, and Gross Exports and Imports Index Numbers (1979–1981=100), 1961–1995



West Africa, irrigated sorghum in Sudan, striga-resistant sorghum throughout much of Africa, tobacco, tea, and coffee all provide examples of how TDT has been able to contribute significantly to African agricultural production

The emergent picture is one of considerable success in African agricultural TDT, despite the difficulty of the tasks that have been faced. This success notwithstanding, there are sobering issues about the effectiveness with which national and regional systems conduct TDT activities, and their efficiency in translating innovative techniques into broad-based social impacts. Any serious attempt to improve Africans' welfare through investment in agricultural TDT must confront these issues.

This document (a) provides a synthesis of what is known about the results of agricultural TDT programs in Africa and (b) defines an agenda for action over the coming decade. The document is intended to stimulate debate among analysts, policymakers, donors, and African governments about funding, priorities, and expected outcomes. The remainder of the document is divided into three parts: Chapter 2 reviews the evidence to date on effectiveness and impacts of TDT programs, Chapter 3 reviews experience with institutionalizing impact assessment (IA) and integrating IA activities within African research and policy-making institutions, and Chapter 4 concludes by identifying a strategic agenda for future IA activities.

2. Evidence to Date

2.1. EVIDENCE ON IMPACT

2.1.1. *Types of Impacts Measured*

Agricultural technology development and transfer (TDT) affects virtually all aspects of the economy, from short-run changes in export/import volumes and domestic prices, to long-run changes in health and nutrition, employment, institutional development, and economic growth. Each of these TDT impacts could be addressed separately to identify the specific effects of any particular TDT program. For example, research on food crops in deficit areas could be expected to reduce imports and improve nutrition, while research on cotton might be expected to increase export earnings and nonfarm employment. Specific impacts of each research program can be documented where local decision-makers need those details for use in guiding their work. But it is also important to look across different kinds of agricultural TDT programs and compare them with alternative public-sector activities in other sectors such as transport, education, health, and environment.

To examine the overall contribution of TDT activities to a country's standard of living and economic growth rate—which quantifies the aggregate impact of TDT on people—we must add up many different kinds of impacts using a common yardstick. This is done by assessing the monetary value of each change caused by TDT, in terms of its *social opportunity costs*, or what it would cost to achieve that effect using other kinds of interventions. In this way, the monetary value of costs and benefits from alternative investments can be assessed on a common scale, for comparison and priority-setting.

A range of possible methods can be used to measure economic costs and benefits, but in practice the economic value of changes caused by research are most often evaluated using a “partial equilibrium” approach in which all the costs of production are

summarized in a supply curve, and all its benefits are summarized in a demand curve. The area between the supply and demand curves is known as economic surplus, which may be divided into “consumers’ surplus” (between the demand curve and the price level) and “producers’ surplus” (between the supply curve and the price level). Research or other public-sector intervention can shift these curves, thus changing consumer and producer surplus.

Consumers’ surplus measures the benefits to consumers of the purchase and consumption of agricultural products at a specified price—usually the market price. These benefits occur because the intrinsic value to consumers of the products exceeds what they pay for the products (except at the margin). Successful TDT affects consumers’ surplus by lowering the market price and increasing the quantity supplied to the market. The poorest of the poor—rural smallholders who are net purchasers of food—are helped by lower food prices and increased quantities available, as are urban consumers. Thus, consumers’ surplus captures the benefits of improved nutrition due to increased consumption of foodstuffs. More importantly, for staple foods, consumers’ surplus captures the benefits to consumers of lower food prices. These benefits include the ability to reallocate income previously spent on food to other needed items, such as health care or sanitary housing. Thus, consumers’ surplus is a complex measure that captures many of the improvements in humanitarian objectives arising from successful agricultural TDT.

Producers’ surplus measures the benefits to producers of increases in productivity and production. The change in producers’ surplus is equivalent to the change in net farm incomes arising from the productivity increase.

Using economic surplus to measure the value of TDT or other investments is popular because it exploits readily available data on prices and quantities to permit reliable comparisons of overall costs and benefits, without having to investigate each specific ef-

fect in detail. The resulting overall “price tag” should be supplemented with detailed evidence on specific effects whenever policymakers are interested and the data can be made available.

Research programs, like other government activities, typically involve making short-run investments to create longer-term benefits. The internal rate of return (ROR, also known as IRR) concept is used to summarize that year-to-year stream of costs and benefits using a single number, which is the percentage “interest rate” earned on the initial investment in returning the longer-term benefits. Thus, ROR results can be compared directly with other kinds of interest rates, particularly the rates paid for loans or received from other investments. The ROR is perhaps the most useful single number summarizing the efficiency of investment in agricultural TDT and is a useful tool for policy decisions regarding the level of investment in agricultural TDT.

2.1.2. Impacts to Date: Aggregate Evidence

Before turning to ROR results measuring the economic value of research, it is useful to survey more direct evidence of its effects. Although countries’ individual experiences are highly complex and uneven, a clear pattern emerges from aggregate data. Food and Agriculture Organization (FAO) data reveal that in the 1960s production, exports, and imports performed relatively well (Figure 1.1). From 1971 to 1984, agricultural production per capita fell consistently, for a cumulative decline of 22 percent, from an index value of about 115 in 1971 to a value of 90 in 1974. The fall in per capita production translated into a much larger proportional change in decline in exports and rise in imports, as the volume of agricultural exports fell over 40 percent, and the volume of agricultural imports more than tripled.

Africa’s agricultural decline was dramatic but limited to the period between 1971 and 1984. The onset of the decline can perhaps be linked to the Sahelian drought of 1972 and 1973, and its end may be linked to good rainfall in Southern and Eastern Africa in 1985. But Africa as a whole did not experience a prolonged drought during this whole period.* Sustained agricultural weakness during the entire

1971–84 period must have been due to causes other than rainfall.

Some clues as to the nature of agricultural stagnation are provided by U.S. Department of Agriculture (USDA) data on average cereal-grain yields. Figure 2.1 shows the data separately for all sub-Saharan Africa, West Africa, and the Sahel from 1960 to 1995, in order to demonstrate the common trend even in the driest area where yields are lowest. During the 1960–95 period, the continent, region, and subregion show somewhat different year-to-year variation, but a strikingly similar 20-year period of yield stagnation from 1964 until the data’s lowest point in 1984. Most remarkably, after 1984 there is a sustained improvement in yields through 1995 in all three areas.

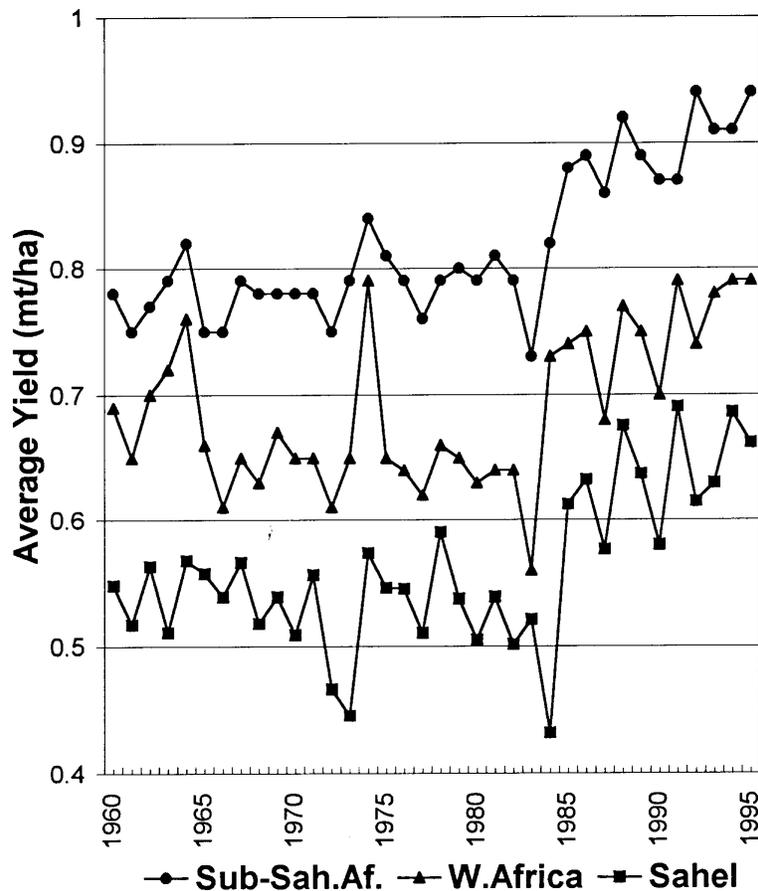
Total production, shown in index-number terms on Figure 2.2, is a result of both yields and area. Again, USDA data show a break after 1984, which is most dramatic for the Sahel. All three areas had an approximately 50 percent increase in total cereal grain production from 1960 to 1984. In the following decade, Sahelian production doubled, while smaller increases were registered in the rest of Africa.

Clearly, there are many reasons why Africa’s agricultural decline ended in the mid-1980s. Policy reforms associated with structural adjustment programs are clearly important, as is improved rainfall in some regions, reduced population growth, and relative political stability. But Africa’s success in increasing average cereal yields also points to an untold story of successful technology development and transfer, as farmers have adopted increasingly productive seed varieties and production techniques.

Some of the increase in crop yields after 1984 documented in Figure 2.1 is due to the more intensive use of existing technologies made possible by policy reform. But some of it is also due to the release of new varieties and new techniques developed by African National Agricultural Research Systems (NARS) and their overseas partners. As with Rhodesia’s crash

* For details on the recent history of Africa’s climate, see Nicholson, Kim, and Hoopengarner (1988) and Le Houérou, Popov, and See (1993).

Figure 2.1. Average Cereal Yield in Africa, West Africa, and the Sahel, 1960–1995



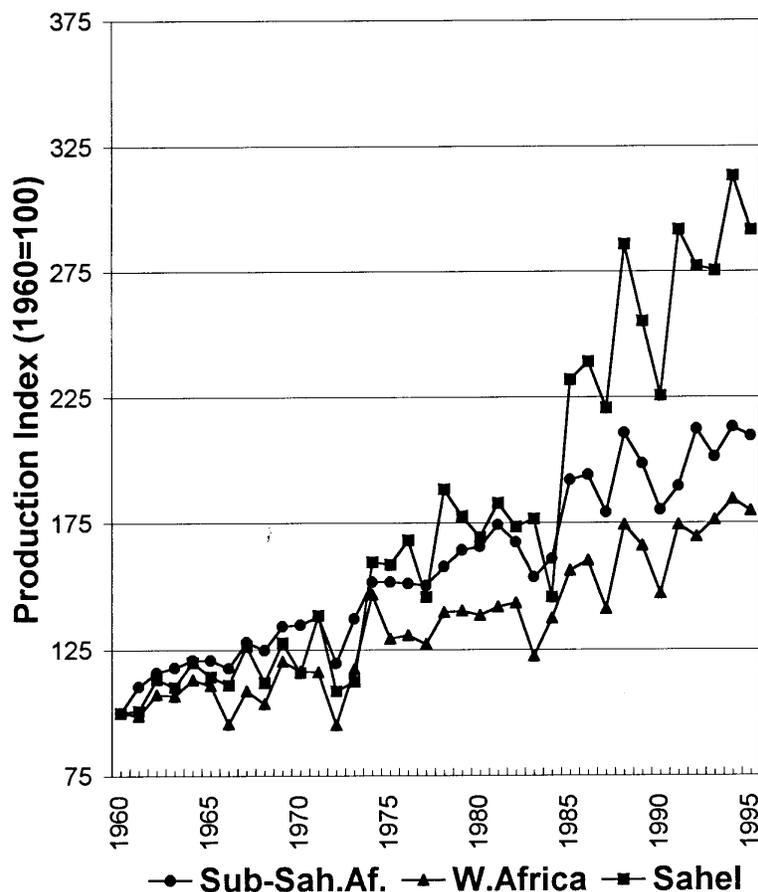
program to develop drought-tolerant maize hybrids, which began in 1966 and released R201 and R215 10 years later, crop breeding programs typically take a decade or more to produce results. Across Africa, the fruits of the research programs initiated after the 1973–74 food crisis began to reach farmers only in the mid-1980s.

2.1.3. Impacts to Date: Rate-of-Return Evidence

To assess the contribution of research to Africa’s agricultural recovery and economic growth, it is helpful to proceed on a case-study basis, with IAs of individual research programs. The research programs evaluated in these studies may not be a random sample of research activity. They do, however, cover

programs facing heavy criticism as well as those seen as successful, and they include a broad cross-section of the major types of research programs. Our compilation confirms that returns to research in Africa are similar to those found elsewhere, showing high pay-offs for a wide range of programs. The contribution of research to agricultural performance and economic growth is not easily visible, since it occurs gradually and is spread widely across the population, but careful investigations generally find the net benefits to be significantly larger than the funding provided. Perhaps the most striking result of this compilation is that, of the 27 estimated RORs found in the literature, only 7 are below 12 percent—and the costs of these relatively poor performances would be more than offset by the numerous cases of very high returns.

Figure 2.2. Cereal Production in Africa, West Africa, and the Sahel



A second striking result from our compilation is that the research failures are often—but not always—in the most difficult agroecological regions. Several competing hypotheses could explain this result. The first and perhaps dominant view is that payoffs tend to be lower in lower-potential areas because the environment's low reserves of soil and water limit any possible production increases. A second and more nuanced view is that those productivity-enhancing innovations which are discovered in these regions are limited in their applicability, due to the diversity of micro-environments found in low-rainfall areas. But neither of these hypotheses is consistent with the sustained yield increases observed for the Sahel as a whole shown in Figures 2.1 and 2.2. This evidence suggests that sustained productivity growth in very dry regions is not only possible but also applicable to a relatively large and varied area.

Perhaps the most compelling hypothesis for the relative failure of past programs in some low-yield areas is simply that researchers had not (yet) found the right mix of activities to produce cost-effective solutions for these environments. Researchers have had to develop entirely new strategies, having slowly discovered the limited transferability of the methods developed earlier in the Americas, Europe, and Asia. Despite Africa's late start, there is evidence that higher-impact innovations are emerging, as researchers gain experience working in these zones. In sum, the relatively low level of returns achieved to date in some difficult environments does not imply that research should move away from these areas—but only that new kinds of innovation are needed. To the extent that people must continue to live in these areas, and will continue to rely on their meager agricultural

resources to survive, research-driven productivity growth can make major contributions to their real incomes.

2.1.4. Impact to Date: Socio-Cultural-Environmental Impacts

Since the economic quantification of benefits implicitly incorporates many sociocultural impacts, such as the value to consumers of lower prices that allow them to purchase a higher level of nutrition for their children, only a few case studies have explicitly quantified such results. One such example is the Lilja and Sanders (1996) study of cotton technology in Mali, which found that technical innovation can decrease womens' incomes even when household income rises (see Box 2.1). The impact of this income fall on health and nutrition is not yet known.

A second set of issues surround the ideas of sustainability. The relatively long time frames required for impact assessment (IA) of investments in TDT suggests that careful investigation should reveal the beginnings of impacts on sustainability. Unfortunately, there is not yet a widely accepted definition of sustainability (see Batie and Taylor, 1991). Long-term yield trends do not show evidence of deteriorating growth. Interestingly, some of the more successful maize innovations in the past three decades have involved extending the area on which maize can be grown by breeding for low-moisture conditions by developing earliness for drought escape and thereby enabling maize to enter areas that are traditionally millet and sorghum producers. The sustainability of maize farming under low-input conditions is unclear. A second interesting example is that of Kenyan wheat. Makanda and Oehmke's (1996) analysis of national data suggests that yield growth is faster since 1960 than in the prior 40 years, although the causes of this higher growth rate are indeterminate. Wheat in Kenya is often grown on somewhat fragile soils, can be subjected to severe rust attacks, and is often used in a rotation pattern. It is thus possible that monocropped wheat yields might be less sustainable, but that with continual research to maintain rust resistance, the Kenyan farming systems have incorporated wheat in a manner that allows for significant yield increases

that are sustainable for at least three decades.

Dalton and Masters (1997) present a more formal definition of sustainability of a sequence of innovations. They formalize and provide the seminal application to Africa of the idea that sustainability can be defined not in terms of any single technique, but relative to a sequence of innovations and innovative practices that eventually lead to higher and possibly sustainable yields. An application to sustainability of soil moisture and nutrients in southern Mali shows that a sequence of individually unsustainable innovations can in fact be sustainable (Box 2.2).

2.1.5 Projected Future Impacts

To examine the potential impact of current and future TDT, ex-ante RORs are often calculated based on projected expenses and benefits. The disadvantage of the ex-ante approach is that research is an inherently uncertain process, and it is often difficult to make accurate projections of adoption, use, and impact, particularly in changing socioeconomic conditions. The advantage of the ex-ante ROR is that when care is exercised in the projections, this method allows more accurate prognostication about the relative impacts of ongoing or nascent TDT activities than does simple extrapolation from historical record as quantified by ex-post RORs. The Uganda case study provides an example (Table 2.2). The ex-post RORs to Ugandan oilseed activities are negative, reflecting the large upfront cost of reconstructing much of the research infrastructure, institutions, and results that were destroyed during the 1980s, and the short time since then in which to generate new results, see them adopted, and achieve impact. Projected or ex-ante RORs that include the future benefits of current activities are likely to be of much more use for investment decisions. More generally, the vast number and magnitude of socioeconomic changes in Africa—considerable time and expense has been invested in strengthening African national and regional TDT organizations, many African countries have recently undergone some sort of structural adjustment and/or devaluation experience, the world has engaged in free trade agreements, South Africa has enfranchised the majority, etc.—suggest that continued investment in research should be based on TDT agendas

Table 2.1. Summary of Ex Post Rate-of-Return Studies for African Agricultural Technology

Author(s) and Date of Study	Location, Commodity, and Years Covered	ROR (%)	Comments
Abidogun (1982)	Nigeria, cocoa	42%	
Makau (1984)	Kenya, 1922–1980, wheat	33%	Econometric methods.
Evenson (1987)	Africa, maize and staple crops	30–40%	Aggregate RORs by region. Econometric.
Karanja (1990)	Kenya, maize, 1955–1988	40–60%	Econometric. Statistical separation of research from extension; seeds.
Mazzucato (1992)	Kenya, maize, 1978	58–60%	Using Karanja data, finds minimal effect of fertilizer policy on ROR.
Ewell (1992)	East Africa, potato, 1978–1991	91%	Regional network/NARS collaboration.
Sterns and Bernstein (1992)	Cameroon, cowpea, 1979–1991; sorghum, 1979–91	3% <0%	ROR to research and extension.
Howard, Chitalu, and Kalonge (1993)	Zambia, maize, 1978–1991	84–87%	ROR to research, extension and seed distribution.
Schwartz, Sterns, and Oehmke (1993)	Senegal, cowpea, 1980–1985	31–92%	ROR to research-based famine relief includes all aspects of TDT.
Mazzucato and Ly (1994)	Niger, cowpea, millet, and sorghum, 1975–1991	< 0%	Non-adoption of varieties released in the study period.
Laker-Ojok (1994)	Uganda, sunflower, cowpea, and soybean, 1985–1991	< 0%	Six-year study period used due to civil unrest in previous 15 years.
Boughton and de Frahan (1994)	Mali, maize, 1969–1991	135%	Introduction of maize into cotton system by Compagnie Malienne pour le Developpement des Textiles (CMDT).
Sanders (1994)	Ghana, maize, 1968–1992 Cameroon, sorghum, 1980–1992	74% 2%	New cultivars with additional inorganic fertilizer. One new cultivar (S-35).
Smale and Heisey (1994)	Malawi, maize, 1957–1992	4–64%	Improved research performance since 1985.

Table 2.1. Summary of Ex Post Rate-of-Return Studies for African Agricultural Technology (cont.)

Author(s) and Date of Study	Location, Commodity, and Years Covered	ROR (%)	Comments
Kupfuma (1994)	Zimbabwe, maize, 1932–1940	43.5%	Research and extension activities of the Department of Research and Specialist Services
Khatri, Thirtle, and van Zyl (1995)	South Africa, aggregate agriculture	44%	Econometric decomposition of agricultural productivity growth
Ahmed, Masters, and Sanders (1995)	Sudan, sorghum, 1979–1992	53–97%	New cultivar (HD-1) introduced in irrigation scheme, with additional inorganic fertilizer and erosion control.
Seck, Sidibé, and Béye (1995)	Senegal, cotton, 1985–1993	34–37%	New cultivars; moderate to high levels of inorganic fertilizers was already in use.
Mudhara et al. (1995)	Zimbabwe, cotton, 1970–1995	47%	Research and extension by the Department of Research and Specialist Services; Department of Agricultural, Technical and Extension Services; and Cotton Research Institute.
Ouedraogo, Illy, and Lompo (1996)	Burkina Faso, maize, 1982–1993	78%	Varietal improvement.
Ouedraogo and Illy (1996)	Burkina Faso, stone dikes, 1988–1994	7%	Natural resource management / soil and water conservation technique.
Seidi (1996)	Guinea Bissau, rice, 1980–1994	26%	New cultivars for mangrove-swamp areas.
Makanda and Oehmke (1996)	Kenya, wheat, 1921–1990	0–12%	Based on econometric estimation of research impact on average yield.
Akgungor et al. (1996)	Kenya, wheat, 1921–1990	14–30%	Time-series econometric analysis of Makanda data. Shows an increasing rate of yield growth since independence.
Isinika (1995)	Tanzania, all crops, 1972–1992	33%	Total factor productivity approach for the crop sector.

Sources: Oehmke and Masters (1997), Mudhara et al. (1995), and Isinika (1995). See the reference list for individual citations.

that consider these issues in their design and attempt to generate impacts accordingly. The ex-ante approach is designed to project impacts consistent with current and anticipated future conditions, and so is particularly suited for informing investment decisions. Moreover, ex-ante results may be most appropriate for addressing concerns such as the sustainability of resources and resource use in the 21st century.

2.2. LESSONS LEARNED

This section focuses on new lessons learned from recent IA studies. The particular lessons are chosen both because the issues addressed are important to future investment in African agricultural TDT and because the ROR studies have significant contributions to make toward resolving these issues.

2.2.1. Technology for Semi-Arid Regions

There is currently a debate about whether to invest in “high-potential” areas with good rainfall and satisfactory soils, or in semi-arid and resource poor areas. Breeding and other agricultural research activities have demonstrated the most success in semihumid areas and with some crops such as rice in humid areas. The IA work sheds light on some interesting issues related to investment in semi-arid areas.

Traditional breeding activities have had limited impact in semi-arid areas in the absence of irrigation or other investment in soil fertility and moisture. For example, development of sorghum varieties for the Gezira irrigation scheme in Sudan is enormously successful, yet sorghum, millet, and cowpea breeding research generates only modest impacts in the drier rainfed areas. Short-season cultivars for drought escape often have the disadvantage of not being able to take advantage of normal or good rainfall years. Often in these years, yields can be reduced by increased disease incidence. Another approach is first to change the water availability/soil fertility situation by providing water harvesting techniques and soil fertility amendments. Then longer season cultivars can take better advantage of the improved environment (Sanders, Shapiro, and Ramaswamy, 1996; Shapiro et al., 1993).

Box 2.1. Technology and Womens’ Income: An Example from Cotton Technology in Mali

Farm households in the Sahel are among the largest in the world. Over a hundred people may live in a single compound, walking several kilometers to outlying fields and grazing areas. Typically, an older man manages a set of “household” plots, while his wives and other relatives—both women and men—labor on those fields and also cultivate “private” plots for food and other personal and living expenses.

Advocates of women’s rights argue that some technical change to intensify production on the common plots can harm the women and younger men, as they may not be sufficiently compensated for the increased labor required of them. This could be the case if women had to divert their labor away from their private plots in order to meet the increased demand for labor on the communal field.

Research in the cotton-producing areas of Mali (Lilja and Sanders, 1996) has shown that some such exploitation does in fact occur. There is typically compensation associated with increased work on the common fields, but its value is significantly less than the cost of reduced production on private plots that results from reduced labor availability. The design of future research agendas may wish to reflect this issue, possibly by packaging some sort of socioeconomic component into the extension of the technical innovation.

Emerging work suggests that investments in natural resources management (NRM) techniques prior to or at the same time as breeding research may generate higher payoffs. For example, Mazzucato and Ly’s (1994) examination of millet, sorghum, and cowpea in Niger leads them to conclude:

In Niger, research has been primarily focussed on genetic breeding, which is highly resource intensive. While the present study shows positive returns to investment in this research program, it does raise questions as to whether such an investment should be maintained. Productivity gains based on varietal improvements have been hard won in the difficult production environment in Niger. This is particularly so for millet and sor-

Box 2.2. Sustainability of a Sequence of Innovations: An Example from the Agro-Pastoral Systems in Southern Mali

As population grows, land use becomes more intensive—but many observers worry that recent yield increases cannot be sustained over time. It is felt that farmers are “mining” their soils, pulling nutrients from the soil’s organic-matter reserves and degrading its structure, leading to an irreversible loss in production potential (for example, van der Pol 1991).

Dalton and Masters (1997) examine the long-run sustainability of current and potential farm techniques in southern Mali. Using a detailed biophysical simulation model, they find that farmers’ crops are usually subject to so much moisture and heat stress, and the plants are spaced so far apart, that nutrient uptake is limited and very little soil mining actually takes place.

Projecting farmers’ options forward into the future, Dalton and Masters find that adopting new seed varieties is already profitable, and that doing so provides a major stimulus to

adopt increasingly labor-intensive management of crop residues and animal manure in subsequent years. This organic fertilizer provides a moisture-retaining mulch, which in turn makes use of inorganic fertilizer increasingly attractive over time.

Careful empirical analysis leads clearly to a stepwise intensification process over the coming years—initiated by the introduction of new varieties but followed quickly by increasingly labor-intensive agronomic techniques, and then increased use of purchased fertilizer. Although no one technique in this sequence is sustainable for very long, the sequence as a whole is both environmentally and economically sustainable over the entire foreseeable future. Agricultural research plays a key role in enabling farmers to sustain production growth, through both the new seed varieties and the new agronomic techniques.

ghum, where thousands of years of natural selection have given rise to a number of good local landraces.... In a country where soil and water are the main productivity constraints, and with a cattle population of 15 million, it seems appropriate ... to focus ... on improved crop and resource management and related areas in animal production (p. viii).

The only ex-post ROR study of soil or resource improvements is that of stone dikes in Burkina Faso, which generated an ROR of 7 percent (Ouedraogo and Illy, 1996). What is interesting about this study is that there are many activities promoting stone dikes in Burkina Faso. The one with the 7 percent return was investigated because it was controversial and generally considered less successful than the others due to its use of collectively built dikes as opposed to individual household construction activities. The modest ROR achieved is thus indicative of high potential payoffs to lower-cost, better-targeted NRM technology projects. Ex-ante studies of Zaï in Burkina Faso and rock phosphate in Mali all show high poten-

tial RORs, thus providing some corroborative evidence of the possibility of impact from investment in ANR research and technology transfer.

The difficulty in working in semi-arid environments does not mean that appropriate new varieties should not be released for use in these areas. Indeed, farmers are willing to adopt good new varieties, and such innovations can improve sustainability (Box 2.1). However, it is not always easy to develop appropriate varieties for current conditions, nor are local landraces always the product of thousands of years of selection. In this case, the breeding strategy should perhaps be to target potential varieties that respond to appropriate agronomic innovations—which in most of semi-arid Africa is labor-intensive soil and water conservation activities—recognizing that the sequence of adoption will vary greatly. NRM adoption studies indicate that the determinants of NRM adoption are very much the same as the determinants of varietal adoption (for example, Sanders, 1994; Clay, Reardon and Kungasniemi, 1997): profitability of the technique, cost, cash flow, labor requirements, etc. This

Table 2.2. Summary of Impact Studies of African Agricultural Technology with Ex-Ante ROR or Benefit-Cost Ratio Results

Authors and Date of Study	Location, Duration of Project, and Technique	Cassava	ROR or B-C Ratio	Annotations
Norgaard (1988)	Africa, 1977–2003	Cassava	149:1	Benefit:Cost ratio, attributes much of the value of cassava production to mealybug control.
Schwartz and Oehmke (1990)	Senegal, 1981–2005	Cowpea	63%	TDT impacts consist of improved household food security and scientist training.
MacMillan et al. (1991)	Zimbabwe, 1991–1996	Maize	1.35:1	Benefit-cost ratio for outreach and demonstration of improved varieties for smallholders. Implied ROR of 22%.
Henry de Frahan et al. (1991)	Mali Farming-Systems Research (FSR)		1%	Evaluated potential of FSR in Mopti region.
Sterns, Schwartz and Oehmke (1993)	West Africa, 1981–2017, Training		22–31%	Private returns to scientist training.
Laker-Ojok (1994)	Uganda, 1985–2006:	Maize Sunflower Soybean	27–58% 10–66% <0–20%	
Sterns and Bernsten (1994)	Cameroon, 1979–98:	Cowpea Sorghum	15% 1%	Cowpea TDT introduced a new farming systems; sorghum TDT added a drought-escape variety useful about one year in three.
Mazzucato and Ly (1994)	Niger, 1975–2011	Millet, Sorghum, and Cowpea	2–10%	Low RORs attributable to few varietal releases (3 millet and 1 cowpea) and low adoption of released varieties.
Bertelsen and Ouédraoga (n.d.)	Burkina Faso, 1990–2003	Zai	53%	Zai is an indigenous knowledge technique of incorporating organic fertilizer in sorghum and millet, planting holes before introducing the seed.
Fisher, Fall, and Sidibé (1995)	Senegal, 1995–2004	Rice	66–83%	New cultivars and inorganic fertilizer.
Tre (1995)	Sierra Leone, 1976–2010	Rice	18–21%	New cultivars for mangrove swamps.
Anandajayasekeram et al. (1995)	Zimbabwe, 1980–99 Namibia, 1988–99	Sorghum Millet	22% 11%	New cultivar (SV-2) New cultivar (Okashana 1)
Kuyvenhoven, Becht, and Ruben (1996)	Mali Rock Phosphate		43–271%	Assumes 50% of production value due to phosphate.
Aghib and Lowenberg-DeBoer (n.d.)	10 countries, 1985–2009	Sorghum	58%	Evaluates 8 INTSORMIL striga-resistant varieties in 10 countries. Includes WVI extension & their costs.
Chisi et al. (1996)	Zambia, 1983–2005	Sorghum	12–19%	12% assumes current level of adoption; assuming 75% adoption gives a 19% ROR.

Sources: Oehmke et al. (1991); Masters, Bedingar, and Oehmke (1996); Chisi et al. (1996).

further suggests that whatever the sequence, breeding, agronomy, and NRM can and must work together for sustainable intensification to occur.

2.2.2. Regional Collaboration

The ROR evidence indicates that regional programs in Africa have had impact. Evidence from the Evenson (1987) study of International Agricultural Research Centers (IARCs), Anandajayasekeram et al. (1996) on the Sorghum and Millet Improvement Program (SMIP), Ewell's (1992) analysis of the potato network in East Africa, and Sanders' (1994) work on Semi-Arid Food Grain Research and Development (SAFRGRAD) each indicate high returns to these programs. Yet each of these studies largely neglect a comparison of alternative ways of organizing the research agenda. IA studies to date have not quantified the cost and benefits of regional programs relative to the costs and benefits that would be achieved if each country in the region carried out its own version of the regional activity (an exception is Maredia 1993). Mazzucato and Ly (1994) cite the decision of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) not to work in 400mm rainfall areas as contributing to Institut National de Recherches Agricoles du Niger (INRAN) difficulty in varietal development, but have no hard evidence to suggest what would have happened had ICRISAT acted differently.

Descriptive analyses generally argue that regional programs increase efficiency over separate national programs in three ways:

- *Regional synergies:* Regional synergies occur when the whole of the activities conducted in the region exceed the sum of the individual activities. One way in which this can happen is through interactions among the scientists in the region. For example, if each country in the region is working on resistance to a particular pest, then pooling ideas may result in a multi-pronged approach whose results are better than those generated by any individual country. Another way in which regional synergies may occur is if regional organization of the research agenda can increase

market impacts through trade or other cross-border effects. One example might be imposing regional grades and standards on products for distribution outside of the region, so that purchasers can have confidence in the quality of the product they are buying.

- *Reducing duplication:* There is often little need for each of 10 or 12 countries in a region to conduct the same or similar experiments in each of 10 or 12 different experiment stations. Some degree of scientific duplication is needed to insure replicability of results, but much existing overlap is unnecessary. Similarly, technical assistance is often contracted for on a county-by-country basis, and the same specialist may be brought back to another country in the region a few months later.
- *Improved ecosystem management:* Many natural resources are shared across countries, such as lakes, rivers, game parks, etc. Negative forces, such as plant pathogens, livestock disease, and resource degradation, may also pose common challenges to the national agricultural systems in the region. Effective development of shared agroecological systems and natural resources requires a regional approach.

Many of these possibilities for increasing impact through regional collaboration overlap with IARC mandates, and IARCs have the potential to strengthen the ability of national agricultural research institutions (NARIs) to collaborate on other possibilities.

2.2.3. Borrowing vs. Developing Technology

One of the critical issues in planning for future research is the decision as to the appropriate strategy: should African countries try to research and develop their own agricultural innovations, or are research resources better invested in borrowing existing techniques from other research institutions and adapting these techniques to particular agroecological and socioeconomic circumstances?

The early history of African agricultural technology is largely one of colonists creating their own

research organizations, often with financial or other support from the colonizing government. Technical innovations arising from these organizations include the development of hybrid maize in Southern Rhodesia at about the same time as in the United States (Box 2.3); development of cattle and small ruminant cross-breeds suitable to African conditions (for example, see Nyaribo-Roberts, 1992); development of livestock vaccines and treatments for African livestock diseases; etc. Kenya wheat breeding is a fascinating example of how these organizations developed. In 1907 rust decimated the wheat crop. One of the earlier colonists, Lord Delamere, responded by hiring a breeder to develop rust-resistant wheat. Still working for Lord Delamere, the breeder was seconded to the Scott Agricultural Laboratory after its construction and operation by the government of the Kenya Colony (Makanda and Oehmke, 1996). The ability of rust rapidly to mutate rendered the first varieties obsolete almost as soon as they were released, and an ongoing breeding program was established. Since

1920, Kenyan agricultural research organizations have released an average of 2-3 new wheat varieties per year (Makau, 1984). In each of the examples discussed in this paragraph, original research and development by African institutions, rather than borrowing, has been a large component of the technical success. The resulting techniques have made significant contributions to improved African welfare.

Borrowing agricultural techniques that have been developed elsewhere has also contributed significantly to improvements in African welfare. The *Compagnie Malienne pour le Developpement des Textiles*' (CMDT) borrowing of maize technology for use in its cotton system gives the highest estimated ROR. (Table 2.1). In this case, the CMDT took an existing variety, developed area-specific agronomic recommendations, and extended a package including the variety and recommendations. With the development of the IARCs, regional platforms to help coordinate national research efforts, and advances in communication technologies, it is likely that borrowing will be in-

Box 2.3. Maize TDT: A Success Story in Southern Africa

Perhaps the most dramatic colonial success story is the development of hybrid maize in Southern Rhodesia/Zimbabwe. Since the 1900s, maize had been a target for research in Southern Rhodesia, partly because it was a local food crop, but mostly because it was also a major export for settler farmers.* With their strong political and financial support, successive Rhodesian governments supported a world-class scientific breeding program which produced a series of highly successful hybrids aimed at settler production, from SR-1 (released in 1932, at roughly the same time as the first corn hybrids were released in the United States) through SR-52 (released in 1960 and still widely planted today).

In 1966 Rhodesian researchers launched a crash program to develop maize hybrids for the relatively dry, sandy, central parts of the

country. The area's short rainy season and low soil nutrient levels mandated early maturity and short stature, to escape drought and concentrate scarce nutrients in the grain instead of the stalk. These breeding objectives were very different from those that had made SR-52 a great success in the higher-rainfall, more fertile north of the country, where high stature and slow maturation were key to maximizing yields. In 1977 and 1978, after a decade of research, the Rhodesian program released R201 and then R215. These short-season, short-stature hybrids proved to be enormously successful among subsistence-oriented smallholders as well as export-oriented settler farmers. After the end of the war in 1980, an array of government policies promoting rural investment and market development promoted adoption. R201 and R215 have replaced almost all existing open-pollinated maize varieties and large areas of sorghum and millet as well. With the exception of drought years, Zimbabwe is largely self-sufficient in grain production.

* Details of the Zimbabwean experience are drawn from Masters (1994) and the historical sources cited there. See also Rukuni and Eicher, eds. (1994) and Rohrbach (1988).

creasingly important in the future. Mareedia and Byerlee (1996) argue that wheat varieties developed by the International Center for Wheat and Maize Improvement (CIMMYT) can be used throughout the world (after varietal screening for ambient conditions) and provide as high or higher yields than varieties developed by countries for their specific conditions. While it may be a bit premature for a country like Kenya to reduce their wheat program on this basis (Makanda and Oehmke, 1996), this type of borrowing deserves a long hard look. Similarly, the increasing use of CIMMYT materials in maize hybrids (over 50 percent of African improved maize varieties use CIMMYT material, in varying degrees [Byerlee and Heissey, 1996] and the increasing involvement of the private sector in maize seed production suggest that borrowing maize varieties will become increasingly important over the next few decades. If IARCs are able to supply most of the needed varietal developments, NARS may be able to focus their activities on increasing the availability of water and improving soil fertility.

The development of transgenic techniques and the emergence of transgenic innovations also has implications for African borrowing of agricultural technology. Development of improved transgenic techniques and maintenance of gene pools for transplantation is perhaps most cheaply accomplished at the regional, continental, or global level. African countries could “borrow” these innovations by screening transgenic materials under local conditions to insure that beneficial outcomes are obtained and that injurious mishaps are minimized. To date, little work has been done on African IA of transgenic varieties or of institutional innovation to maximize benefits, yet this is clearly a direction of the future.

2.2.4. Institutional Innovation in NARIs and NARSs

Institutional innovations in NARIs and NARSs are needed to institutionalize research success and impact. That is, research organizations can strengthen themselves by redesigning research processes and institutional procedures so that the natural outcomes of the organization are advances in scientific knowl-

edge that ultimately improve human well-being. Certainly research success occurs as part of a systemic process in some cases. For example, the ROR to Malian maize research focuses on the CMDT system, which introduced maize as a secondary crop into a well-functioning cotton system, as part of a conscious choice emerging from the organization’s decision-making apparatus. By comparison, maize has had minimal impact in the neighboring and agroclimatically comparable Operation Haute Vallée (OHV) region of Mali, because the OHV is a less effective organization (Boughton, 1995; Dione, 1989). Kenya and Zimbabwe have had considerable success in maize research, at least among larger farmers and in high-potential areas, helped in part by the well-functioning input and output distribution systems in these areas (Karanja, 1992; Kupfuma, 1994). Zimbabwe has had similar success in developing cotton production in commercial areas (Mudhara et al., 1995). Yet these examples are exceptions to the rule.

In general, African research institutions have failed to create themselves along lines that make research success a likely outcome, and in some cases, these institutions even inhibit success. African research impacts have too often been generated by a few good scientists working in an ambivalent or even inhibiting research and extension environment. For example, Howard (1995) attributes the successful development of improved Zambian maize varieties adapted to smallholder conditions to the “mulish” pursuit of hybrid development and adaptation by the head breeder, even in the face of system directives to cease such activity, and the breeder’s ability to act as liaison with farmers.* The success of the research-based famine relief activity in Senegal rests in large part on the restructuring of the extension and distribution systems (as the existing structures were inadequate) for the duration of the project, and the underlying germplasm collection that had previously been undertaken largely by a single scientist, Djibril Sene (Schwartz, Sterns and Oehmke, 1993; see also Bingen,

* The impact of these varieties was greatly augmented by a nationwide, publicly financed input and output distribution system with large throughput, but which had high costs that led to financial problems and ultimately the collapse of the distribution system.

Hall, and Ndoye, 1988). The development of improved flint maize varieties in Malawi is largely due to the willingness of a few scientists to test the conventional wisdom that it is difficult to develop a high-yielding variety with flinty grain characteristics. Too often, research institutions acquire “organizational dynamics that stifle even ‘the best and the brightest’” (Bingen and Simpson, 1996, p. 13).

A critical need in the institutional development of most NARS is the creation of a culture that makes research success and impact the path of least resistance. As noted above, a number of critiques of African agricultural research institutions detail the inhibiting factors in NARS as they are currently structured—low salaries, inadequate operating expenses, lack of accountability, lack of or misprioritization of activities, fluctuating funding levels, inadequate exchange of information with other NARS, etc. While some general rules of thumb have been published and are helpful, they do not deal with the diversity of individual circumstances faced by countries with different agroclimatic characteristics, political systems, social goals, and agricultural heritage (for summaries of steps in this direction see Boughton et al., 1995; Rukuni, 1996; or Byerlee and Eicher, forthcoming(b)). Tripp (1993) argues, “Public sector agricultural research requires significant reorganization, including the assumption of more responsibility for its own direction and output” (p. 2013). Individual NARS have been slow to mold themselves into the types of institutions that can adapt to and influence research and other agricultural policies. In other words, it is clear that institutional paradigms can be improved, and indeed must be improved if agricultural research is to provide the stimulus needed to generate and sustain agriculturally led economic growth in the 21st century.

2.3. AGGREGATE AND ROR RESULTS IN COMPARATIVE PERSPECTIVE

The aggregate and ROR evidence presented here helps explain why productivity growth in Africa has occurred later and less dramatically than the “green revolution” of the 1960s and 1970s. Much productivity growth in the green revolution areas of Asia and Latin America was

driven by the adoption of short-stature fertilizer-responsive crop varieties, in the context of relative moisture abundance—and led to sharp rises in marketed surplus of food grains (Falcon, 1970). Africa’s agricultural intensification shares many features of the Asian and American green revolution, notably increased use of inputs and labor to sustain higher crop yields per hectare. But there are also major differences, and Africa’s productivity growth is clearly less visible than that of Asia in its impacts on farmers’ fields or marketed surplus. A significant portion of Africa’s productivity growth has occurred through early-maturing varieties aimed at short rainy seasons—and often in food-deficit environments, where marketed surplus consists of livestock, oilseeds, cotton and other products (Sanders, Shapiro, and Ramaswamy, 1995). In eastern and southern Africa, important advances in maize productivity and production have resulted from successful research and technology transfer (Gilbert et al., 1992; Byerlee and Eicher, 1997). This research, including early development and use of hybrid varieties, is largely obscured, and the canonical story of successful maize research remains the story of hybrid development in the United States. The facts show that, while African agricultural research has had its difficulties and low points, it does yield and has yielded impressive economic gains from improvements in the level and stability of farmers’ income, and in terms of national economic growth.

Appreciating the contributions of African agricultural research requires recognition of two issues: defining the appropriate measure of aggregate performance, and delineating the counterfactual situation of what would have happened in the absence of agricultural TDT.

Certainly sustainable economic growth, including increased access to food, is the overriding social goal that motivates investments to stimulate agricultural growth and increase the contributions of agriculture to non-agriculture growth, such as investments in agricultural TDT. Yet there are many factors that facilitate—or hamper—economic growth. Thus, measuring the economic growth rate in a country is a poor way of indicating the performance of agricultural TDT. For the evaluation of the aggregate impacts of agricultural TDT, it is critical to measure accurately the contribution of agricultural TDT to growth, and then to determine

whether that contribution—not the overall growth rate—is appropriate. Similarly, a comparison of the growth rate of agricultural production with population growth rates, while of undeniable social importance, provides only *misinformation* about the performance of the agricultural sector. African population growth rates at or in excess of 3 percent per annum are so abnormally rapid that no agriculture in the world could keep up a similar growth rate for a sustained length of time. (For example, the real value of U.S. agricultural output grew by an annual average of 1.69 percent over the period 1889–1990 (Huffman and Evenson, 1993)) Therefore, growth rates of African agricultural output of less than the typical African population growth rate are not indicative of the failure of African agriculture. Rather they are evidence of the need to address a broad range of social issues.

More specific measures exist for quantifying aggregate agricultural performance and contributions to the resolution of broad social problems such as food insecurity. These measures, though not frequently used, show a far less gloomy picture of African agriculture. For example, Block (1994) provides the first application to Africa of the agricultural-output-aggregation method that Hayami and Ruttan (1985) used so fruitfully on Asian data. Block's conclusion is that:

Introducing [the Hayami-Ruttan] output aggregate substantially alters the findings regarding African agricultural productivity. In place of a picture of consistent productivity decline painted by the other output aggregates, the ... data suggest that after fifteen years of stagnation, African agricultural TFP (total farm productivity) increased substantially during the mid 1980s, growing at roughly 2% per year from 1983 to 1988 (p. 621).

Block finds that up to one-third of the growth in agricultural TFP is attributable to past investments in agricultural research. It is a reasonably straightforward step to then calculate the contribution of these increases in agricultural TFP—for example, along lines suggested by Dinopoulos (1996)—and use this contribution as one measure of aggregate impact. For example, if agriculture contributes one-third of the gross national product of the economy, then a rough calculation suggests that agricultural research con-

tributed almost a quarter of a percentage point to African economic growth over the period 1983–1988. This is a sizable contribution in terms of economic growth and is consistent with the relative magnitude of aggregate investment in African agricultural research over the period—less than 1 percent of agricultural product (see Pardey, Roseboom, and Beintema, 1997).

The second issue that is critical to recognize is the appropriate counterfactual situation: What would have happened in the absence of agricultural TDT? For example, Gilbert et al. (1992) argue that as much as one-half of the contribution of maize TDT has been in sustaining prior yield increases, which would have been lost in the absence of research. At the case study level, evaluations of agricultural TDT are usually very careful to consider what the appropriate counterfactual situation is, and perhaps also to engage in sensitivity analysis to compare other possible counterfactual situations. Determining an aggregate counterfactual situation is much harder. Although they do not address agricultural research per se, Sachs and Warner (1996) take an important step by estimating the determinants of growth rates in an attempt to answer the question of why Africa grew slowly relative to other developing countries. They arrive at some interesting conclusions regarding African economic growth:

First, African countries have a higher level of natural resource dependence than other developing countries. This is estimated to have reduced their growth relative to other less developed countries by 0.2 percentage points per year. Africa also followed more closed policies than other developing countries. Protectionism is estimated to have further reduced Africa's growth by 0.7 percent per year. Africa's greater share of land-locked countries is estimated to have reduced growth by 0.2 points. Africa's less efficient economic policies, (other than openness) is estimated to have reduced growth by 0.3 points. And finally, Africa's lower savings rate is estimated to have reduced growth by a further 0.9 percentage points.

Taking all of these factors together, we estimate that Africa should have grown about 1 percent per year *slower* than all other less developed countries during the period 1970–1990. In fact Africa grew

0.85 percentage points slower than other developing countries [pp. 4–5, italics and parenthetical remark in original].

The implication is that slow African economic growth during the 1970s and 1980s can be explained without recourse to an unmeasured concept of agricultural failure. Sachs and Warner conclude that previous attempts to explain Africa’s slow growth failed “to account for the effect on growth of Africa’s closed economic policies (p. 5).”

Clarification of the contributions of African agricultural TDT clearly requires additional work—both

theoretical and empirical in scope. Yet the evidence available to date indicates that investments in agricultural TDT have contributed importantly and significantly to improvements in individual welfare, and that these improvements are large enough to prove the economic value of the investments. Moreover, emerging evidence suggests that agricultural TDT has given a small but important boost to the economic growth of African economies relative to what growth would have been without investment in TDT, even in the relative is relatively stagnant 1970s and 1980s.

3. Building Capacity and Institutionalizing Impact Assessment

The primary purposes of conducting impact studies are to help mobilize resources for agricultural technology development and transfer (TDT) and to improve the efficiency of the funded TDT activities. A key condition for efficient resource allocation is the institutionalization of IA as a planning tool. IA activities cannot be institutionalized without developing the necessary human capital. Thus capacity building and institutionalization are closely linked and considered to be priority activities of the regional initiatives. This section summarizes the approaches adopted by the various regions in sub-Saharan Africa (SSA) with respect to capacity building and institutionalizing IA and the lessons learned.

Institutionalization of IA process is defined as the permanent integration of IA as a planning tool in the research process. The approaches adopted by the various regions in SSA vary, largely due to the existing regional institutional structures. The various approaches adopted are considered appropriate under those circumstances but are converging towards a common set of conditions.

3.1. INSTITUTIONALIZATION OF IMPACT ASSESSMENT AND PLANNING: CURRENT STATUS

Previous research cited weak institutionalization of planning and assessment activities in Africa as a general problem. Particular difficulties arise in (1) conceptualizing the role of research in the broader context of agricultural transformation (i.e., recognizing the link between research impact and broader sectoral characteristics such as input supply and output markets, and designing research strategies aimed at improving the policy and organizational environment into which technology is launched, as well as developing technology); (2) establishing and maintaining a core staff of trained socioeconomists to

assist programs with planning and assessment, and, more broadly, maintaining attractive conditions of service (including salary, training opportunities, and funding for research activities) for all researchers; (3) conducting IAs; and (4) relating IA to planning (i.e., using lessons from ex-post and ex-ante IA studies to inform planning efforts, and reallocating resources on the basis of these studies).

3.1.1. Conceptualizing the Role of Research

The responsibilities placed on national agricultural research institutions (NARIs) have increased dramatically over the past decade. In the early 1980s, NARIs and NARI scientists were responsible primarily for “good science”: ensuring that experiments and investigations addressed the issues at hand using appropriate techniques, and that the results—including varietal releases, agronomic recommendations, livestock husbandry techniques, etc.—were legitimate conclusions of the experiments. Scientists and administrators predominantly assumed that good science would naturally lead to significant improvements in social welfare.

The disappointing aggregate performance of African agriculture and increasing donor demands for ‘accountability’ have led donors and others to demand not only that NARIs provide good science, but also that they be held accountable for their social impacts or lack thereof.

The early IA studies demonstrated a number of points relevant to the relationship between good science and social impact. First, the generally high rates of return (RORs) provide at least some corroboration that good science, when undertaken by scientists seriously concerned with the well-being of their fellow humans, can and does have positive social impacts. This could be partially attributed to the farming-systems research (FSR) programs currently being institutionalized in many sub-Saharan countries. Second, improvements can be made so that NARIs do a

better job of facilitating scientific research and so that the resulting social impacts are increased. Third, in many cases the magnitude and breadth of the social impacts are constrained by socioeconomic forces. These three points lead to the conclusion that impact studies can play a continuing role in helping to make research resources more productive in generating social impact. In particular, the recognition of socioeconomic forces and the role they play in determining the social impact of scientific innovations can improve research agendas, budget and manpower allocations, and even the nature of varietal releases and other innovations disseminated. IA is one way of analyzing these socioeconomic forces. The fourth point that emerges from the early IA studies is that many biophysical scientists feel uncomfortable or untrained in analysis of socioeconomic forces, including how to incorporate socioeconomic results into their own research programs and agendas.

The first step in the IA and planning agenda is then to sensitize National Agricultural Research System (NARS) scientists and administrators to the need, potential benefits, and the implications for institutionalizing IA as a planning tool. In the regional IA initiatives, this is largely accomplished through country visits, discussions, and national and regional workshops. The details of the national sensitization workshops completed during the 1993–1997 period in the Southern Africa Development Committee (SADC) region are presented in Table 3.1. These workshops have enabled the countries to develop a strategy for institutionalizing the IA process within the research and extension services, as well as the training within the higher learning institutions.

3.1.2. Establishing a Core Staff

3.1.2.1. East Africa

In East Africa, U.S. universities (Purdue and Michigan State) and USAID's Regional Economic Development Support Office / East and Southern Africa (REDSO/ESA) have played lead roles. In each case, U.S. collaboration reaches the NARS both directly and through existing regional institutions, with training and collaborative case studies as a means to achieve institutionaliza-

tion and capacity building. Collaboration has involved both relatively strong national systems (e.g., Kenya) and relatively small ones (e.g., Rwanda/Burundi). At the regional level, collaboration has occurred primarily through the Association for Strengthening Agricultural Research and Training (ASARECA) and through REDSO/ESA-sponsored training activities. Some commodity networks, with assistance from the relevant IARCs, have also initiated IA activities.

ASARECA has been established to coordinate research and training activities in Eastern Africa. It is anticipated that this institution will take a lead role in developing strategies and implementing activities on behalf of the region to build capacity and institutionalize IA at both national and regional levels. Capacity building and institutionalization began largely through the regional research networks supported by USAID. Michigan State University (MSU) is also looking at the issues of planning and priority setting in East Africa. In October 1996, ASARECA coordinated a workshop for the Ethiopia, Kenya, Tanzania, and Uganda NARIs, backstopped by International Service for National Agricultural Research (ISNAR) and MSU, to share experiences on the use of IA in regional planning.

3.1.2.2. West Africa

In West Africa, Purdue University has provided extensive training through regional workshops, collaborative case studies, and long-term degree programs. These activities are designed to nest in one another. At the broadest level, the regional workshops have permitted over 50 scientists from a dozen NARIs to initiate impact studies themselves. Of those, more than ten scientists from four NARIs have become involved in collaborative case studies, and seven NARIs researchers have moved into long-term degree programs at Purdue.

The short-term workshops, held annually in Bamako, Mali (June 1994 and 1995) and Niamey, Niger (July 1996), have combined three elements:

- hands-on training in the use of economic surplus methods, using computer exercises based on actual NARS case studies;

**Table 3.1. Regional and National Sensitization Workshops,
SADC Member States, 1993–1997**

Country	Date	Number of Participants	Target Audience
Swaziland	Nov. 22–23, 1993	42	Board Members, Senior Researchers from Food, Agriculture, and Natural Resources (FANR) sectors, team leaders of regional (SADC) research programs and International Agricultural Research Center and donor representatives.
Malawi	Feb. 28 – Mar. 1, 1994	41	Senior and middle-level managers, ANR researchers, extension officers.
Zambia	June 18–22, 1995	39	Senior and middle-level research and extension managers, academic staff—staff of planning unit, and the environmental council.
Namibia	Aug. 8–10, 1995	32	Staff and senior and middle-level managers from the Ministry of Agriculture, Water, and Rural Development; Ministry of Environment and Tourism; Ministry of Lands, Resettlement, and Rehabilitation; Ministry of Fisheries and Marine Resources; Directorate of Extension and Engineering Services; Oxfam Canada; European Commission; Namibian Botanical Research Initiative; and NGOs.
Tanzania	Sept. 18–20, 1995	37	Senior and middle-level managers from the Ministry of Agriculture (research, extension and planning) Research Foundation and Forestry Institutes.
S. Africa	Apr. 14–17, 1996	58	Staff and middle-level managers from Agricultural Research Council, National Departments of Agriculture, Provincial Departments of Agriculture, and agricultural universities.
Mauritius	August 11-16, 1996	51	Staff and middle-level managers from Agricultural Research and Extension Unit, Food and Agriculture Research Council, Agricultural Services, Mauritius Sugar Research Institute, Irrigation Authority, Agricultural Marketing Board, Farmer Service Co-operation, Fisheries Research Center, Chamber of Agriculture, University of Mauritius, Mauritius Research Council.
Botswana ²	March 16-22, 1997	30	Same as biological scientists training workshop.

¹ Sponsored and conducted by the National Directorate of Research and the Southern Africa Center for Cooperation in Agricultural Research and Training (SACCAR) using an existing USAID grant.

² National sensitization and training combined.

- presentation and peer review of past studies done by workshop participants; and
- presentation and peer review of workplans for upcoming impact studies.

The training material has been disseminated beyond the workshop participants through an *Impact Assessment Manual*, published in both French and English along with computer exercises for use in replicating previous studies, and spreadsheet templates for use in other analyses.

The collaborative case studies, undertaken since 1994 have involved work with researchers at Institut d'Economie Rurale (IER) in Mali, Institut Senegalais de Recherches Agricoles (ISRA) in Senegal, Institute d'Etudes et de Recherches Agricoles (INERA) in Burkina Faso, and Institut National de Recherches Agricoles du Niger (INRAN) in Niger, building on the technique presented in the regional workshops, but also moving towards more detailed studies of technology adoption and impact using household models.

In 1996 Purdue University gave the first training in farm level ex-ante technology evaluation with programming in Mali. In 1997 the Institut du Sahel (INSAH) agreed to add this to the regional training in economic surplus to be given in Burkina Faso. This is now expected to be a regular component of annual Francophone training. Also in 1997 the first Anglophone course in economic surplus techniques for West Africa will be held in Ghana.

In Purdue's degree training programs, students typically return to their home institution during the summer break to present work in progress and collect data for future activities. This ensures that training activities and research topics remain closely linked to the workplan of the home institution, and facilitates reintegration at the end of the degree program.

Purdue has recognized the need for a regional coordinating body to effectively institutionalize IA initiatives within the region. So far IA has been effectively integrated into the existing regional research networks. Purdue is trying to reach the NARS in West Africa, through INSAH. The problem is that this agency is only responsible for Sahelian countries. Attempts are currently being made to work with INSAH so that they could perform the coordinating

functions on behalf of the region.

In addition, Purdue and MSU are working on key methodological issues to keep the knowledge frontier moving forward.

MSU, Centre de Coopération Internationale en Recherche Agronomique par le Développement (CIRRAD), and others have worked with INSAH and IER to backstop development and implementation of the commodity sector approach to IA and research planning. This approach has been successful both in generating IA results (for example, Boughton and Henry de Frahan, 1994) and in identifying constraints to and opportunities for increased impact (Boughton, 1995).

3.1.2.3. Southern Africa

In the case of Southern Africa the lead role for capacity building and institutionalization was assumed by the Southern Africa Center for Cooperation in Agricultural Research and Training (SACCAR) in 1993. A large number of regional research and training networks are being coordinated by SACCAR and are executed by IARCs. To build capacity and institutionalize the process, SACCAR adopted a strategy to simultaneously deal with the regional networks and the NARS. The objectives of these two strategies are:

- To develop the regional capacity to undertake impact assessments of ANR research activities;
- To assist in the institutionalization of the process both within NARS and with the regionally executed projects; and
- To assist in the institutionalization of IA training.

At the regional level, SACCAR is establishing a need-based monitoring and evaluation (M&E) system as an integral part of the project management. Activities related to developing IA capacity and institutionalization of the process at the NARS level include:

- Sensitizing NARS management on the need for IA as a management tool in decision making and its implications. This is accomplished largely through visits, discussions and workshops.
- Regional and in-country training on IA method-

- ologies for economists and biological scientists.
- Collaborative case studies with NARS scientists.
- Development of a procedural manual on IA for use by NARS scientists.
- Training of trainers.
- Assistance in the incorporation of IA methodologies within academic training programs.
- Assistance in the establishment of data base and M&E systems for TDT evaluation as an integral part of research management.

In addition to the regional strategy for capacity building and institutionalizing IA, a national strategy for institutionalizing IA exists in Malawi, Zambia, Namibia, Tanzania, South Africa, and Mauritius. The regional training on IA methodologies is an annual activity which brings together economists from the NARS in the region. This training workshop is conducted in collaboration with University of Zimbabwe. The total number of individuals trained through the regional training workshops is provided in Table 3.2. A portfolio of approaches are presented and the participants are allowed to choose the most appropriate approach to suit their local conditions. In southern Africa, training workshops for biological scientists have been completed in South Africa, Mauritius, Botswana, and Tanzania (See Table 3.3 for more details). Thus, training activities included both social and biological scientists. Several regional and national impact studies have been completed and five national studies are on-going. Two sets of teaching notes have been developed for biological and social scientists. A core group of regional trainers participate in all national and regional training activities. Training includes short-term (skills) training and on-the-job training. At present, two of the trainees are planning to use the case studies for their doctoral and masters theses, respectively.

Recently NARS managers in East and Southern Africa were asked to comment on the adequacy of the existing IA capacity at the national level in terms of finance, human skills, and data availability. Eighty percent of the countries responded that the financial and human capacity are inadequate to undertake IA, whereas 75 percent of the countries reported that the existing data base is inadequate (Table 3.4). This

clearly demonstrate the need for continuous support in capacity building and the development of M&E system for the research services. A few of the countries in Southern Africa have included an impact statement—amounting to a form of ex-ante assesment—in the research project proposal. This will assist managers and researchers in allocating the scarce research resources.

After carefully reviewing the experiences, the group agreed that the approaches followed in each of the subregions are appropriate given the diverse circumstance of the region. The approaches were complementary and ideally would be used in tandem. Implementation would be by a regional organization taking a lead role, in partnership with other NARIs and academic institutions. The academic institutions can address the methodological challenges confronting the NARIs and can provide the support in training. The group unanimously agreed that the following are necessary preconditions for effective institutionalization of IA as a planning tool:

1. Established need and commitment by policymakers and senior managers.
2. M&E system for research.
3. Close communication and interaction between biological and social scientists within NARS.
4. Trained personnel to undertake impact studies.
5. Appropriate methodology/procedures. To use IA as a planning tool, there is a need for harmonizing procedures at the national level.
6. Development of an institutional capacity to offer training on a continuous basis.
7. Collaboration and linkages with other agencies including national level coordination of activities.

There was general consensus that the institutionalization is an evolutionary process which requires long-term commitment and assistance.

3.1.3. Institutionalizing Impact Assessment Training

Currently most training activities are largely initiated and conducted by external academic institutions and regional bodies with donor assistance. Effective inte-

Table 3.2. Number of Individuals Completing Impact Assessment Training, SADC Member States, 1993–1997

Participants	1994	Febr. 1995	Aug. 1995	1996	1997	Total
Angola	-	-	1(1)	1	2	4
Botswana	4(2) ¹	3	1	1	3(1)	12
Ghana	-	-	-	1	-	1
Lesotho	1	1	1(1)	1(1)	2(1)	6
Malawi	2	4	3(1)	5(1)	3(1)	17
Mauritius	-	-	-	1	2	3
South Africa	-	2	2	3(1)	8(2)	15
Swaziland	2(1)	2(1)	1	3	3	11
Tanzania	4	4	1	2	3 (1)	14
Zambia	3	2	5	2	1	13
Zimbabwe	2	2(1)	8	5(3)	-	17
Kenya	2(2)	-	-	-	-	2
Namibia	1	1(1)	1	-	1	4
Sierra-Leone	1	-	-	-	-	1
Mozambique	-	-	1	-	-	1
Zanzibar	-	-	1	-	-	1
TOTAL	22	21	26	25	28	122

Observers: Kenya 1

National Resources Sectors: Forestry, Fisheries, Wildlife, Land and Water Management

¹ Figures in parentheses represent female participants.

gration of IA requires continuous training. In the long run, such training should be provided by the national and regional institutions. One way of addressing this issue is to include the concepts and procedures of IA in the teaching programs of the academic institution.

For West Africa, training is largely provided by Purdue University and includes short-, medium-, and long-term training. So far, activities have focused on building the analytical capacity of NARS staff. As the senior staff become increasingly experienced, it may be appropriate to develop local training programs, thus institutionalizing the training activity itself. In East Africa, training is provided by a regional facility, while in Southern Africa, the training is based in one of the local agricultural higher learning institutions. The workshops

are jointly organized and administered by SACCAR and the University of Zimbabwe. University staff from the region participate in the training as well as in training-material development, but it is still not effectively integrated into their academic curricula.

The committee of Deans of SADC recently discussed this issue and resolved to make every effort to find a permanent home for the regional training and to include impact-assessment concepts and procedures into university curricula in the region. Currently two universities in the region are moving in this direction. The group recognized that this is an important activity but that little has been accomplished to date. The group endorsed that, with respect to institutionalization of training, there is a need for:

Table 3.3. Number of Biological Scientists Trained at the National Level, SADC Member States, 1996–1997

Country	Date	Number of Participants	Target Audience / Institution
S. Africa	Oct. 20–26, 1996	49	Agricultural Research Council, National Department of Agriculture, Provincial Departments of Agriculture.
Mauritius	Dec. 2–4, 1996	40	Ten institutions involved in agricultural and fisheries research, training, extension, as well as development activities.
Tanzania	Jan, 18–25, 1997	64	Academic staff of the Faculties of Agriculture, Forestry and Veterinary Medicines, selected Senior Researchers of the Ministry of Agriculture and Livestock.
Botswana	Mar. 16–22, 1997	30	Department of Agricultural Research, Animal Health and Production departments, Ministry of Agriculture, Agricultural Planning and Statistics, Plant Protection Division, Botswana College of Agriculture, National Institute of Research.

Box 3.1. Building Impact Assessment Capacity

The possibility of institutionalizing research IA rests on host-country capacity to conduct the assessments. The authors of the assessments conducted in the early 1990s are, for the most part, still working on issues of African agricultural technology:

- Daniel Karanja completed his M.A. program at Michigan State University with the thesis “The Rate of Return to Maize Research in Kenya: 1955-88.” He then returned to the Kenya Agricultural Research Institute (KARI) for four years to work on the KARI/CIMMYT maize database project and is now back at MSU for his Ph.D. program.
- Rita Laker-Ojok completed her dissertation on “The Edible Oilseed Subsector in Uganda: Can It Compete?” and received her Ph.D. in 1994. She has returned to Uganda and is working there for Appropriate Technologies International.
- David Makana completed his Ph.D. dissertation on “Wheat Policy in Kenya” including work on research impacts, and is receiving his doctorate posthumously.
- Valentina Mazzucato completed her M.A. program with the thesis “Non-Research Policy Effects on the Rate of Return to Maize Research in Kenya: 1955-1988.” Working for ISNAR, Mazzucato spent four months in Niger in a joint ISNAR/MSU project on “An Economic Analysis of Research and Technology Transfer of Millet, Sorghum, and Cowpeas in Niger” (Mazzucato and Ly, 1994). Mazzucato is currently enrolled for further study at Wageningen University.
- Ousmane Coulibaly completed his Ph.D. with the thesis “Devaluation, New Technologies, and Agricultural Policies in the Sudanaian and Sudano-Guinean Zones of Mali” and is presently working for the International Institute for Tropical Agriculture (IITA) in the Cameroon.

Over 200 African scientists have received degree or short-term training related to IA. Most of these scientists remain within, and provide IA capacity for, African agricultural technology systems.

Table 3.4. Existing Capacity to Conduct TDT Impact Assessment

Countries	Resource Capacity			Existence of a National Strategy	Existence of a Formal System
	Financial	Human	Data		
EAST AND CENTRAL AFRICA					
Burundi	I	I	I	No	Yes
Eritrea	I	I	I	No	No
Ethiopia	A	A	I	No	Yes
Kenya	I	I	I	Yes	Yes
Madagascar	A	I	I	No	Yes
Uganda	I	I	I	No	Yes
Dem. Rep. of Congo (formerly Zaire)	I	A	A	No	Yes
SOUTHERN AFRICA					
Angola	I	A	I	No	No
Botswana	I	I	A	No	No
Lesotho	I	I	A	No	Yes
Malawi	I	I	A	Yes	Yes
Mauritius	A	I	I	Yes	Yes
Mozambique ¹	I	I	I	No	
Namibia	I	I	I	Yes	No ³
South Africa	A	I	I	Yes ²	Yes
Swaziland	I	I	I	No	Yes
Tanzania	I	I	I	Yes	Yes ³
Zambia	I	I	A	Yes	Yes
Zanzibar	I	I	I	No	Yes
Zimbabwe	I	A	I	No	No

Key: A = Adequate, I - Inadequate

¹The respondent could not answer this question.

²A strategy exists at the Agricultural Research Council.

³Currently working on establishing a M&E unit for agriculture, but they do have a unit to monitor extremely funded projects.

Source: SACCAR Survey, 1995.

- Well established institutional linkages between the agricultural higher learning institutions and the relevant ministries.
- Recognition of the need, firm commitment, willingness, and flexibility of the policy-making body of the higher learning institutions to meet the requirements of the NARS in terms of providing the required skills.
- Development and/or existence of an institutional capacity to offer training including
 - Availability of professional expertise or trained personnel with the required skills;
 - Resources and facilities to offer such training; and
 - Availability of training materials.
- Preparing the higher learning institutions to offer such training at the national and regional level.

The university training should be complemented by on-the-job training provided by NARS. Issues which require attention with respect to institutionalization and capacity building include:

- Development of an M&E system for research;
- Harmonization of methodology at the national level;
- Human capital development;
- Changed emphasis from ex-post to ex-ante assessment;
- Coordination of impact related activities at the national level;
- Assessing the impact of regional research networks;
- Assessing the impact of extension;
- Assessing the impact of livestock-related R&D activities; and
- Assessing the social and environmental consequences of technologies.

The group concluded that considerable progress has been made with respect to capacity building and institutionalization. Given the fact that institutionalization is a slow, evolutionary, long-term process, efforts should be continued to complete the process.

3.1.4. Conducting Impact Assessments

As pointed out in Chapter 4 of this report, several impact studies are currently being undertaken by

Box 3.2. Eight Steps toward Starting Impact Assessment and Planning (IA&P)

1. Generate a consensus to invest time and money in IA&P, and to use the results—even if only on a test-case basis. Achieved largely through sensitization workshops and meetings.
 2. Select the IA&P test case in consultation with NARS manager.
 3. Select the IA&P team in consultation with NARS manager.
 4. Define IA&P procedures appropriate to the case and time and budget constraints. Specify types of impact to be measured, data needs, collection and analysis methods, etc., in conjunction with stakeholders and possibly analytical experts.
 5. Provide training to team, if needed.
 6. Gather data.
 7. Analyze data.
 8. Write-up results, including recommended actions.
-

NARS in sub-Saharan Africa. The national programs and scientists take a lead role and coordinate these studies with technical input and other support from regional organizations. In the SADC region, a technical advisor (USAID supported) located at SACCAR provides technical assistance.

The case studies are considered as follow up to the regional training program. Upon completion of the regional training, in consultation with the NARS manager, a test case is selected. Then a team is formed depending on the various aspects of the program being chosen. The team and the other stakeholders meet in a planning meeting to work out the details of the study—that is, to define objectives, procedures, resources, data collection methods, data to be collected, and responsibilities of various groups including a time schedule for completion of the work. The team meets at critical stages to complete the study. The first draft report is circulated to all the stakeholders. Based on their comments, the report is revised, published, and distributed to all stakeholders. The country-level case studies are also used in the training workshops as examples.

Unfortunately, such impact assessments are usually conducted on a test-case or sporadic basis. The capacity to assess impact on an ongoing basis and to make the results of such assessments part of the continual process of research planning, agenda setting, prioritization, updating, and revising plans is lacking in most African NARS. A survey of 20 NARIs in East, Central, and Southern Africa shows that not a single NARI has the financial, human, and data resources necessary to conduct IA of TDT (Table 3.4).

3.1.5. Relating Impact Assessment to Planning

Most of the ex-post impact studies can only provide evidence that past investments in TDT activities are justifiable based on people-level impact measured in terms of ROR. Ex-ante impact assessments provide additional information enabling researchers and research managers more efficiently to allocate research resources. In most countries, data as well as other information are not available to conduct an IA of all major TDT activities.

This does not mean to say that the knowledge on IA cannot be used in planning at present. Some of the countries in the SADC region have endorsed the inclusion of an impact statement as a part of the research proposal. This provides some key information that could be used in the planning process. In most regional- and national-level planning, potential impact of TDT activities is used as one of the criteria in priority setting.

3.1.6. Example: The Kenya Agricultural Research Institute

The Kenya Agricultural Research Institute, with assistance from ISNAR, has made significant progress on several of these fronts, by designing and implementing an innovative model for institutionalizing priority setting that uses ex-ante IA and other tools for program-level priority setting. Key features of the KARI model are:

- (1) the establishment of a senior-level working group charged with (a) defining the criteria and methods to be used in priority-setting exercises, (b) oversee-

ing the development of an institutional structure to collect information, and (c) reviewing the results of program-level priority setting exercises as a basis for a comprehensive institute-wide priority setting exercise planned for 1997;

- (2) the full integration of program scientists into all planning and assessment activities; and
- (3) hands-on training for socioeconomists and program scientists in practical tools for assessment, including a geographic information system to classify research target zones and computer-based spreadsheet models.

These are important achievements, particularly the innovation of a high-level committee to coordinate planning and assessment activities across the institute. Countries may want to consider the following issues as they adapt the model to their own needs, however. First, the KARI program-by-program approach is expensive; research systems with fewer resources may wish to focus planning and assessment activities on a few key programs. Second, the KARI approach (completing all program-level assessments in preparation for an institute-wide review planned for 1997) leaves a long time lag between implementation of planning and assessment activities and decisions about actual resource reallocation. This does not preclude reallocation prior to the review: evidence from IA of a growing maize yield gap between farm fields and experiment station instigated a reallocation of personnel from breeding to agronomic activities. However, there is no evidence yet that resources have been reallocated either at the program or institute levels as a result of KARI's institute-wide planning process. In Kenya and elsewhere in Africa, hesitation in reallocating resources is partly linked to the difficulty of shifting human capital between research areas or physical locations, but also to residual pressures from donors who wish to continue to fund and control special projects.

Tanzania, Uganda, and Ethiopia have each carried out IA and planning activities, but these activities are less well institutionalized than in the KARI model. Nor are the links between IA and research planning well established. There have been important innovations aimed at bridging the gaps between researchers and research clients, and in broadening the research agenda to include policies

and organizations affecting research impact, however. Tanzania and Uganda have experimented with techniques to elicit better participation from research clients, including off-farm agribusinesses. In each country, programs are undertaking contract research and/or soliciting greater core contributions from farm groups and agribusiness clients, and in turn providing these client groups with more control over the research agenda and involvement in M&E and IA. In Ethiopia, plans are underway to launch a major assessment of maize research that explicitly considers the impact of government policies on the adoption and spread of improved maize technology in the past, and implications for future maize research, policies, and organizations needed to promote agricultural intensification.

3.2. LESSONS, ISSUES, AND FUTURE DIRECTIONS IN INSTITUTIONALIZATION

IA remains a relatively new experience in most African NARIs. Sensitization workshops have been successful in demonstrating that IAs can provide information valuable for research planning, but a great deal of experiential learning and learning by doing remains to be accomplished before IA is institutionalized as part and parcel of research planning. This section delineates some of the more pressing issues germane to moving ahead with institutionalization.

3.2.1. Capacity Building for Impact Assessment

The previous section clearly shows the lack of capacity in African NARIs for IA. Building this capacity is the most critical area in moving forward. Training scientists in assessment methods has had the most noticeable effect, with over 200 scientists trained. However, until these scientists are given the mandate and funding actually to conduct assessments, this training will not be put to full value. Consequently, generating the administrative mandate, mobilizing funding, and acquiring sufficient data as well as continued strengthening of human capacity are the critical elements of continuing to build capacity.

3.2.2. The Interface between Biophysical and Social Sciences

Successful IA relies on the cooperation of biophysical and social scientists. This suggests that placing of social scientists on teams of biophysical scientists may be the best organizational structure in which to conduct IA. Past experiences with farming systems research suggests that social science positions may not be filled quickly, if at all. Moreover, out-posting the social scientists makes it difficult to compare findings for incorporation into organizational priorities and agendas. Having a central social science unit alleviates these problems and may reduce the number of social scientists needed overall. However, a central unit runs the risk of not being able to communicate effectively with biophysical teams, especially those based at experiment stations and especially if funds for operating expenses are low. A central unit also runs the risk of being perceived as a unit of evaluators, rather than as scientists providing socio-economic information for use by all members of the TDT institution. Additional work on these institutional design questions is needed.

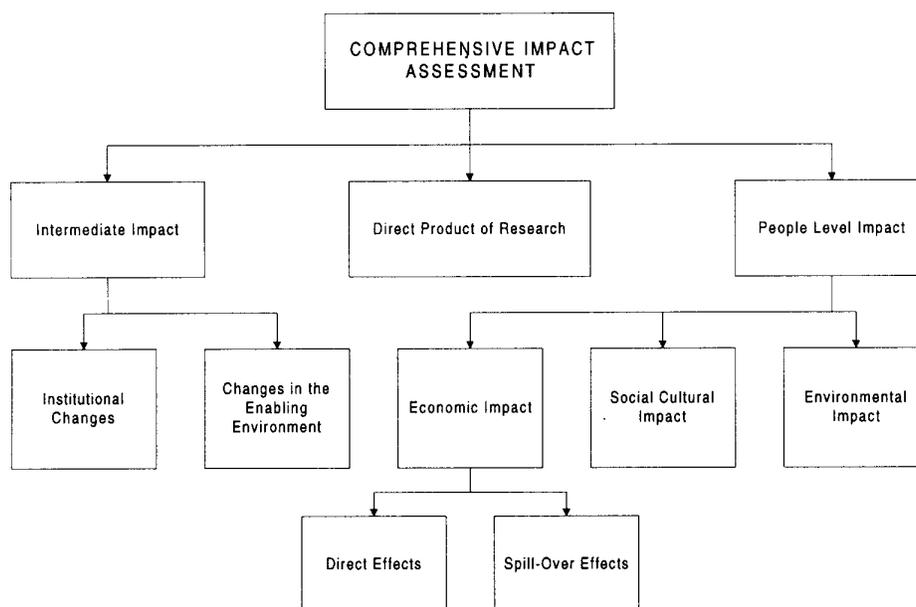
3.2.3. Including Stakeholders

How to include stakeholders in research design and conduct remains a problem in developed and developing countries alike. This is particularly a problem if farmers' organizations under-represent the smallholders that are the target of much publicly funded TDT. Participatory research is one approach, but is implemented primarily at the project level and less so at the organizational level.

3.2.4. The Interface between NARIs and Internal and External Factors Influencing Impact

Perhaps the most critical issue in institutionalizing IA is the interface between NARIs and those factors—internal and external—that most influence the impacts of research. For example, suppose that an IA suggests that millet research for remote areas has had limited impact because of cross-border trade restrictions. Does this

Figure 3.1. Comprehensive Impact Assessment



suggest that the NARI reduce millet research, lobby for trade agreements, initiate a rural development program to promote millet use in the remote area, or something totally different? The answer will depend on specific circumstances, including the resources available to the NARI both for internal use and for influencing external factors. Making such decisions is part of strategic planning for TDT. Generating and incorporating IA results into such strategic decisions in a purposive way is the hallmark of a fully institutionalized IA program.

A comprehensive IA can be thought of as covering all possible benefits and costs of the technology agenda (Figure 3.1). It is one way of placing the economic numbers in a broader context. The comprehensive IA not only includes economic, social, cultural and environmental impacts, it also examines direct impacts of research within the technology system and institutional changes throughout the agri-

cultural system, including within the research organizations itself. Particularly in an ex-post assessment, some consideration should be given to as many benefits and costs as is feasible. For example, intermediate impacts may contain institutional innovations within the NARI that allow the NARI better to address stakeholder needs, such as greater exchange of ideas and innovations through participation in a regional research organization. Intermediate impacts may also change external constraints, such as facilitating a relaxation of restrictions on cross-border transport of planting materials. Recognizing the possibility of such impacts may alter the research protocols used (for example, from breeding to screening) and improve the efficiency with which the TDT is conducted, as well as increase the impact generated when innovation is successful.

4. Towards a Strategic Agenda for Impact Assessment

IAs currently are undertaken by national or regional organizations largely to mobilize funds: that is, to respond to the needs of donors and other providers of funds, justifying either that past funds have been used efficiently or that the current agenda has a high potential payoff. This is certainly a legitimate use of IA. However, the result of this idiosyncratic approach to determination of IA subjects means that important issues may go unaddressed. For example, the paucity of studies on the impact of water and soil management techniques for semi-arid regions or regions with poor soils means that IAs to date are insufficient to fully inform the debate about how best to improve agricultural productivity and sustainability in these areas.

A strategic agenda for IA is a description of outstanding issues in generating improvements in social well-being from TDT that (1) can be informed by IA, (2) will help to satisfy donors and other funding agents about the impacts generated from their investments, and (3) will help NARIs and other participants in the broader TDT system better to allocate their efforts and resources. Conjoining the last two items must be done by the relevant donors, NARIs, and regional agricultural research institutes (RARIs). This section outlines the more important issues that can be addressed by IA; the importance of these issues suggests that related IA will also be useful both in mobilizing and allocating funds.

4.1. CURRENT STATUS

4.1.1. Use and Usefulness of Impact Assessment

Impact assessments of African agricultural research have been extremely successful in generating new funds from donors such as USAID/Washington (USAID/W) and the World Bank, even in the presence of declining budgets, as demonstrated in earlier

sections. There has been a smaller degree of success to date in generating new funds in the field, such as from USAID missions. This is possibly due to three factors: missions have less flexibility in reallocating funds on an annual basis than does USAID/W; the outreach and communication of results and lessons is more difficult and time-consuming on a continent-wide basis than within the District of Columbia; and the closing and/or restructuring of missions has created difficulties in reallocating existing funds, with budget problems creating difficulties in obtaining new funds.

The key impacts of IA are:

- *Influence on World Bank Funding.* Based on the results of impact assessments sponsored by USAID, in a 1993 seminar at the World Bank / Africa Technical Advisory Group (AFTAG), Jerry Wolgin stated that USAID now recognized the importance of continued investment in African agricultural research, and hoped that the Bank would come around to that view.
- *Collaboration.* USAID and Michigan State University (MSU) have collaborated via the Food Security II (FSII) cooperative agreement with the Bank, and notably the Special Program for African Agricultural Research (SPAAR), to increase research funding and to provide a strategic perspective for improving the efficiency of investments in TDT.
- *Renewed interest in research impact assessment.* Donors, Africans, and researchers have renewed their interests in IA for agricultural TDT. This interest is typified in the set of IA studies currently being undertaken by the Southern African Center for Coordination of Agricultural Research and Training (SACCAR), and proposed by the newly formed Association for Strengthening Agricultural Research in East and Central Africa (ASARECA), a committee of Directors General of the NARIs.

- *Methodological lessons.* Improvements in the speed and quality of IA methods within the African context are drawn from the completed IA studies. Dissemination of methodological innovations has occurred at workshops in West Africa sponsored in part by the USAID Bureau for Africa (USAID/AFR) and USAID/Mali and hosted by INSAH, in Southern Africa sponsored by USAID/REDSO/ESA and hosted by SACCAR, and in East Africa sponsored by USAID/REDSO/ESA and hosted by ASARECA.

These impacts form important components of the USAID/AFR Office of Sustainable Development agenda of fostering agricultural technology development and transfer to stimulate broad-based economic growth in sub-Saharan Africa.

4.1.2. Costs of Impact Assessment Studies

The initial set of impact studies carried out in the early 1990s was very costly, running nearly \$200,000 per study. The high cost is attributable to two primary factors: (1) the lack of institutional capacity for technology IA in African NARS required that the studies be coordinated from abroad; and (2) the lack of previous impact assessments required establishment of conditions prerequisite to IA, including baseline information on critical variables such as farming techniques used and farm yields. In most cases, some type of farm-level survey was required to generate even basic information on whether or not farmers were utilizing new varieties, recommendations, or other innovations.

Advances in the application of impact studies in Africa have driven the cost down to a \$3,000 to \$10,000 range for studies conducted by in-country researchers with a modicum of backstopping from a regional support organization such as SACCAR or INSAH. This dramatic cost reduction is the result of (1) institutional commitment by NARIs to IA; (2) training of host-country human capacity for conducting IA within NARIs; (3) learning by doing; (4) adequate baseline data and data on adoption and use of NARI innovations, and their impact on farm fields (e.g. milk, grain and stover yields, etc.); (5) regional

Box 4.1. To Invest or Not To Invest

One of the more interesting applications of ex-ante rate of return (ROR) analysis is the application to the semi-arid Region of Mopti in north-east Mali. Having successfully developed technical packages for use in southern Mali, the Malian Institut d'Economie Rurale (IER) investigated using farming systems research to transfer on-station results to Mopti. Henry de Frahan et al. (1989) projected an ROR of 1 percent, which was highly sensitive to yields and prices. Based on these findings, IER chose not to pursue the research activity at that time. The ex-ante analysis thus had the impact of releasing research resources from a potentially low-payoff activity so that they could be used more effectively.

coordination of impact assessments to save costs on methodological development, data analysis, writeup, and dissemination; and (6) low salary levels in African NARIs.

The current concern is that cost considerations will cut IA budgets to the bare bones. This would result in IAs that produce an ROR or other measure based on reasonable but uninspired measures of benefits and costs, with little understanding of what factors make that ROR and the underlying program efficient or inefficient. The value of IA lies primarily in the lessons learned about improving the efficiency of agricultural TDT, not in any single numerical measure.

4.2. LESSONS AND ISSUES

4.2.1. Methodological Issues

Current methods of quantifying benefits and costs are satisfactory for determining whether or not investments in agricultural TDT have generated—or are likely to generate—positive impacts sufficient to justify the investment. Nonetheless, the economics profession constantly seeks to improve our ability to accurately quantify benefits and costs. For application to African agricultural TDT, three particularly

needed improvements are: expanding the types of benefits and costs included in the IAs, more accurately attributing benefits among TDT and complementary activities, and improving the description of the benefits and costs that are included.

Expanding the types of benefits and costs included in the IAs is necessary to account for nonmarket and general equilibrium effects of TDT. Non-market effects occur when TDT improves—or harms—some resource or amenity that is not traded in a marketplace, such as soil fertility, biodiversity, or social or environmental characteristics. In the absence of an observed market price, it may be difficult to determine the value that a particular society places on this resource. For example, it is difficult to place a value on improved income equality. The problem is complicated by the range of values held by particular societies, and the range of societies inhabiting Africa. For example, some Africans may view wildlife as a natural resource to be conserved, others may view it as food to be eaten. Some may view wetlands or floodplains as ecosystems valuable to biodiversity; others may view wetlands as undeveloped paddy-rice land. Each viewpoint has merit.

In the case of cotton in Zimbabwe, 86 percent of the sampled large-scale farmers are using reduced tillage, such as a ripper instead of a conventional plow. This practice reduces not only soil compaction but also soil erosion. Nearly all farmers in the sample scout their fields before using chemicals to control pests and diseases. Large-scale commercial cotton farmers use a combination of mechanical and chemical weed control methods. Low-tillage land preparation, moisture management (tied ridges), and scouting have positive environmental effects; the use of chemicals to control pests, diseases and weeds and cotton monocropping have negative externalities. These environmental consequences of cotton R&D efforts are recognized qualitatively but have not yet been included in ROR estimates (for example, Mudhara et al., 1995). This is due both to lack of biophysical data and to problems with valuation methods. Therefore, in designing technology programs, the issue of collecting data on environmental externalities should be addressed.

Currently, impact analysts usually include a seri-

ous discussion of nonmarket impacts, but don't always quantify these impacts for inclusion in the benefit-cost calculus. In the *Zambian maize study*, Howard (1995) argues that one of the positive impacts of the massive government subsidization of maize production and provision of low-cost food to a large urban population was an improvement in the political stability of a recently independent nation. Surely this is an important contribution. Yet there is no market measure of the value of political stability, and quantifying this value as an economic benefit is at best difficult. A second interesting example is male/female income equality within the household. The Lilja and Sanders (1996) study cited earlier shows that, in southern Mali, the introduction of new cotton techniques on the communally farmed areas increases the labor requirements for those farms, which results in women allocating more time to the communal plots at the expense of their private plots. Even though household income certainly increases, and the women themselves earn additional money from the extra labor on the communal plots, the extra money is insufficient completely to offset the loss of women's income from less active private plots. Over time, some women seem to be able to solve the problem through cooperative action, but such changes in social structure do not arise without painful and costly social conflict.

The second methodological issue—more accurate attribution of benefits—arises because successful TDT often takes place at the same time as success in other development activities, such as infrastructure improvement. It is therefore often difficult to attribute some or all of the benefit to the TDT activity. This raises two questions: have the benefits of TDT been calculated correctly in the benefit-cost analysis, and do the lessons learned provide implications relevant to further investment? To illustrate the issue, consider two hypothetical technical innovations in a semiarid area: an improved millet variety and innovative water harvesting techniques. With just water harvesting, yield increases from 200kg/ha to 600kg/ha; with just the improved variety, yield increases from 200kg/ha to 500kg/ha; but with both, the yield increases to 1500kg/ha (Table 4.1). Thus, an attempt to identify the impact of varietal improvement alone

Table 4.1. Hypothetical Example of Attribution Issue

Hypothetical Yields	Traditional Variety	Improved Variety
No Water Harvesting	200 kg/ha	500 kg/ha
Water Harvesting	600 kg/ha	1,500 kg/ha

could find either 300kg/ha, the improvement in the absence of water harvesting, or 900kg/ha, the improvement if the water harvesting is already in place. In either case, a more appropriate analysis would address the combined impact of the two techniques, which jointly produce a greater impact than either one might do alone.

The question of the accuracy of lessons learned is more important. Suppose farmers adopt first water harvesting and then the improved variety, so that the attribution of yield increase is 400kg/ha to the former and 900kg/ha to the latter. This tends to obscure the real lesson learned: the yield increase from the complementarity between the two innovations is two to three times the yield increase from either innovation in isolation. The implication is that for similar areas, a multifaceted research approach may generate the biggest impact. The critical issue in attribution is that the IA not focus on a single impact measure, but draw forth the lessons about the best portfolio of TDT and other investments to sustainably improve productivity and production.

The third methodological issue—improving the description of benefits and costs included in the IA—is a matter of communicating economic concepts to policymakers and other client groups. Most research IA calculates benefits as improvements in social surplus. These benefits include improvements in producer welfare due to greater net returns from farming or other agricultural activities, and improved consumer welfare due to lower food agricultural prices. The latter is particularly important, since many of the poorest of the poor farmers cannot feed their families on their small land holdings, and so are net purchas-

ers of basic foods (Weber et al., 1988). Lowering the price of food is critical to improving their well-being. Moreover, the social surplus approach to assessing benefits includes the social and household benefits from more affordable food—such as improvements in household health, child nutrition, etc. To break out each of these effects may be very costly and data intensive, and has not yet been done in Africa. But the aggregate measures of consumers’ welfare used in the benefit-cost analysis incorporate the benefits to households from these effects. Since these effects are expressed in economic or dollar terms, it is often not clear to policymakers that these effects are in fact included in the ROR studies. Consequently, greater effort is needed on the part of IA analysts to make explicit the range of potential benefits accruing from agricultural TDT.

A particular example of this problem is that policymakers are uncomfortable with the ROR measure. This suggests several actions, the first of which is much broader than the TDT agenda:

- 1) Management training sessions should be given on topics of investment or project analysis. RORs remain the most useful single measure of the benefits, costs, and time pattern of research investments and impacts. It is important that policymakers understand ROR. This understanding is critically important for continued receipt of donor funds if research managers in developing countries are to determine their own development agenda and supporting investments in an accountable fashion. For example, the World Bank requires ex-ante ROR analysis of projects (with a special exemption for TDT because of the uncertain nature of the research process).
- 2) Possibly researchers could present the results in terms of some measure of project valuation that is largely equivalent in economic terms to ROR, but uses different words. Net present value or annuity value are possibilities. Sanders (1994) reports some success in policy-maker acceptance of these terms. The disadvantage of these measures is that they depend in large part on the size of the project, and may incorrectly be interpreted in a manner that leads to “bigger is better”

project selection. The national sensitization workshops conducted in southern Africa have made important contributions to understanding of ROR measures (Anandajayasekeram and Martella, 1995, 1996).

- 3) As noted above, IA could incorporate explicit quantification of benefits such as increased nutrition, health improvements, etc. Some of these may be fairly straightforward to incorporate, others are more complicated and may require detailed field surveys to generate the necessary information, increasing the cost and duration of IA studies.

4.2.2. Thematic and Programmatic Areas

If IA is to assist in defining research priorities, it must be able to inform questions about the potential payoffs of different research directions. This section discusses the most important of the thematic and programmatic issues that IA can address, and discusses lessons learned to date. In every case, current information is sketchy: each issue is a candidate for further investigation by future IAs.

4.2.2.1. Defining a Research Agenda for Resource-Poor Areas

Much of the evidence to date on a research agenda for resource-poor areas is summarized in section 2.2.1. This evidence suggests that some combination of technical innovations to improve natural resources, harvest water, and improve genotypes can be successful. The evidence is unclear about the sequencing of such technical innovations, and in all likelihood, the sequencing will vary by area and farming system, depending on the current status of the farming and technology systems and how these systems evolve over time. Thus, the evidence provides a modicum of optimism about further investments in TDT for resource-poor areas.

However, economists and social policymakers should not underestimate the difficulty of agricultural research oriented toward resource-poor areas, particularly if economic growth and transformation are the objectives. When research is directed first and

primarily toward resource-poor areas, success usually takes the form of lower yield losses due to poor rainfall by introducing drought-resistant or short-cycle varieties, or otherwise adding stability to a subsistence farming system. Such has been the case with sorghum and millet varieties released in Namibia and Zimbabwe (Anandajayasekeram et al., 1995). Stability may be of critical importance for household food security among the subsistence smallholders farming these areas, but it is unlikely to generate large surpluses and transformation to a market-based agriculture. For example, most cereals crops evidence some sort of tradeoff between the level of photosynthesis and efficiency of water use, (Austin, 1985; Baker, 1989), making it difficult to breed high-yielding varieties for semiarid areas.

Previously, agricultural TDT for resource-poor areas should be oriented less toward development and agricultural transformation, and more toward disaster prevention. In years with poor weather, the people living in resource-poor areas are likely to take the brunt of crop shortfalls and livestock stress. The objectives of TDT in resource-poor areas thus include stabilizing yields and sustaining or enhancing the natural resource base, in addition to increasing income. Investors in TDT for resource-poor areas should recognize and accept stability and sustainability as objectives, and judge the merit of their investments accordingly.

However, it is also necessary to recognize the importance of moving away from the historic process of selecting early material, because this material often does not respond well to normal or good rainfall years or to improvements in fertility. It is not appropriate to condemn these regions to strategies that never involve moderate to substantial improvements in farmers' incomes, as have been achieved in developed countries. The necessary second stage in developing technology for semiarid regions is to alleviate the inadequate availability of water and the low soil fertility. As water harvesting and soil fertility improvements are introduced, breeders must also be producing medium- and longer-term cultivars to take advantage of these improved agronomic conditions (Sanders, Shapiro, and Ramaswamy, 1996; Shapiro et al., 1993).

A final point on semiarid environments is that, once the water availability and soil fertility is improved, semiarid regions have advantages over higher rainfall environments resulting from lower disease incidence. Semiarid regions often become excellent agricultural areas, as has occurred in Australia, Israel, California, and Arizona. Much of the discussion on low resource and high resource regions is sterile if the semiarid zone can successfully and sustainably harvest water and increase soil fertility.

Unfortunately, the benefit calculations used in most ROR and benefit-cost analyses of agricultural TDT do a poor job of including stability and sustainability as measured benefits. This methodological gap, noted above, thus leads to an intellectual gap in our understanding of the differences in impacts of TDT investments in resource-poor areas versus resource-abundant areas. Informing the decisions about (1) the economic tradeoffs in allocating funds across agroclimatic regions with different resource endowments and (2) how best to measure impacts in investments in resource-poor areas are thus critical issues for further investigation through IAs and other studies.

4.2.2.2. Allocating Effort Between Subsistence and Commercial Farming

The impact studies demonstrate that African agricultural productivity and production has increased over the past three decades, but at rate slower than the population growth rate. Nonfarm employment and the urban population have increased at a faster rate than rural society but are still not large enough to absorb all of the increase in total national population. As a result, the farm population will continue to rise for several decades, leading to inexorable growth in labor availability per hectare. Employing the growing labor force while feeding the growing urban population will require steadily more labor-intensive and also more market-oriented farming sector—or else continual reductions in living standards and reliance on foreign aid.

Africa has already demonstrated the capacity to compete in the production of food and export crops under mechanized, large-scale commercial conditions,

Box 4.2. TDT for African Smallholders

African agricultural research institutes have become more attuned to smallholder needs. The development of maize in southern Africa is a good example. Colonial Southern Rhodesia was known for its development of maize hybrids, especially SR1, developed in the early 1930s at about the same time as the first U.S. hybrids, and SR52, a high-yielding, long-cycle variety released in 1960 and still planted widely by commercial farmers throughout Southern Africa.

Following the end of Zimbabwe's war of independence in 1980, two early-maturity, short-stature varieties that had been released previously were widely adopted by smallholders. More recently, the Zambian research system released four short-cycle varieties suitable for low-rainfall areas, and the Malawi research system released a high-yielding variety with flint characteristics desired by smallholders.

None of these "smallholder" varieties outperform SR52 under high input and high rainfall conditions, but they are far more successful in low-rainfall areas. And since these areas actually account for very large shares of total production, the post-independence focus on smallholders actually improved the effectiveness of research as well as its equity.

but such activities are economically inefficient in an environment of high and rising labor availability in rural areas. Since the 1960s, newly independent African countries have redirected their research less toward large commercial farms and more toward smallholders, but even more focus on small-holder agriculture is needed.

The underlying question thus becomes: What is the best way to assist smallholder subsistence farmers to become small-scale commercial farmers, producing more than enough for their own household needs and selling their marketable surplus to increase their incomes and the food supply to other consumers. The transition from subsistence to commercial smallholder needs four components:

- improved techniques, so that farmers can produce more than they need;
- an input market or some other type of delivery system for the improved technique or the inputs embodying them;
- an output market in which to sell their marketable surplus; and
- farmer knowledge and interest in how to use the innovative techniques and participate in markets.

The issue of the relationship between technical change and market development is one of determining how to proceed with the development of the four components.

4.2.2.3. The Relationship between Technical Change and Market Development

To posit a sequencing of technical innovation and market development on purely conceptual grounds is to run in circles: if there are no markets then no farmer will produce a surplus for the market, but if no farmers are producing a marketable surplus, then there is no market. This suggests a strategy of simultaneously investing in market development and technical innovation. The problem with this strategy is that it is too general, providing little in the way of actual investment guidance, and ignores the specifics of market-technology interactions in any particular project area.

The complexity of market-technology interactions reflects the complexity of farm activity itself. African smallholders often produce a variety of products fulfilling a variety of needs, using a variety of inputs. Cash income from one source may be used to invest in something entirely different, often with close links between farm and nonfarm activities. For example, a typical rural household in the semiarid regions of Zimbabwe uses a significant share of its cash income to buy hybrid maize seeds, but rarely sells maize—it raises cash from other sources, including sales of “cash crops” that use few purchased inputs (for example, groundnuts and sunflowers), labor-intensive cottage industries (like brickmaking, basketweaving, and beer brewing), and remittances (that is, seasonal or semi-permanent migration). In

general, purchased inputs are not always used in products for sale, and products sold do not always use purchased inputs.

The issue is to determine an appropriate portfolio of investments in TDT and improvements in accompanying markets. There is a distinct paucity of efforts that examine quantitatively the sequencing of and interactions between market and technical development. For example, Demeke, Said, and Jayne (1996) use a marketing perspective to look at interactions between fertilizer and improved grain techniques to determine how to increase grain production in Ethiopia. The authors provide specific and actionable fertilizer-marketing recommendations with quantification of the cost savings involved in each recommendation. In contrast, their conclusions provide little in the way of specific recommendations for TDT:

The rate and time of fertilizer application, the control of weeds, diseases and pests, the level of organic matter in the soil, drainage conditions (in water-logged areas) and moisture conservation (in water-stress areas) ...[t]he use of complementary inputs and cultural packages are indispensable components [of] the package necessary to improve the efficiency of fertilizers (pp 14-15).

This analysis is symptomatic of the difficulties involved in sorting out the complex interactions that determine the optimal sequencing of investments in technical innovation and input and output markets.

Despite the lack of quantitative evidence on interactions among technical innovations and market development, there is considerable anecdotal and descriptive evidence. A fascinating analysis is the description by Smith et al. (1994) of the introduction of maize into the northern guinea savanna of Nigeria. The authors compared cropping patterns found in a 1989 survey with descriptions of farming systems from the mid-1960s to 1981 (Box 4.3). In the mid-1960s maize was of little importance. By 1989 maize was “one of the three most important food crops in all but one [26/27] of the sample villages, and one of the three most important cash crops in 70% of villages (p. 543).” The authors argue that the underlying causes of this change were the introduction in the

Box 4.3. Maize Intensification in Nigeria

In the 1970s maize was a minor, 'backyard' crop in the northern guinea savanna of Nigeria. By 1987 it was one of the most important food and cash crops in the area. Maize helped to transform the farming system from subsistence to intensive, annual cultivation of food and cash crops. The critical factors spurring this transformation were:

- maize varietal development in the mid 1970s, and
- road improvement in the late 1970s.

Specific characteristics of the cereals sector that allowed continued intensification include:

- TZB yield and profitability advantage,
- maize use as food and its storability,
- reduced reliance on output markets,
- cash compensated for underdeveloped credit markets,
- divisible technology (variety) allowed small-holder participation, and
- fertilizer subsidy.

Source: Smith et al., 1994.

mid 1970s of the TZB maize variety, ideally suited to the agroclimate and to consumers' tastes, and in the late 1970s the construction and improvement of roads. Adoption rates for improved maize varieties are extremely high, virtually reaching 100 percent in over one-half of the sample villages. Following adoption of TZB, farmers also increased fertilizer and animal traction use.

Two interesting findings regarding the sequencing of TDT and other investments arise from the Smith et al. study. The first relates to the need for extension services. A fertilizer and improved seed package was extended by agricultural development projects (ADPs) working in three enclaves. "It should be noted that although the ADPs were concentrated in three enclaves during the maize adoption periods, improved maize spread throughout the region, indicating that when a technology meets farmers' needs, its dissemination is

Box 4.4. Demand for and Production of Malian Maize

The Mali impact study and further analysis by Boughton (1995) provide considerable insight into the relationships between technical innovation and markets. Oehmke (1996) reviewed the Mali evidence, concluding: "(1) when neither input nor output markets function effectively, there is little adoption of technical innovation (evidenced by the OHV/CMDT comparison), (2) the existence of a reasonable input market or other supply mechanism is important to the adoption of innovations, (3) the contribution of these innovations to agricultural transformation is determined largely by the demand for the farm product as expressed through the marketplace, and (4) the existence of a well-functioning, input-supply mechanism for improved inputs is not sufficient to generate market demand for the output." The implication is that investment in the input supply systems is insufficient to generate agricultural transformation even when technical advances are possible. The output market must also be functioning.

possible with minimal extensions" (Smith et al., 1994, p. 547). This finding is consistent with the quantitative literature, which shows that although payoffs to agricultural extensions are generally good in developing countries, extension is rarely a necessary component of successful agricultural TDT (Oehmke, 1997).

The second interesting finding from Smith et al. relates to the sequencing of market and TDT investments. Even though Nigeria has a history of subsidizing fertilizer, prior to the adoption of improved maize there was little fertilizer use in the study area. Fertilizer prices were lower than the import parity price, but remained three to four times the official price. Even at these prices, supply is a problem, "as a result of which farmers have been unable to get as much fertilizer as they wanted at the right time. In spite of these availability problems fertilizer has been widely adopted, indicating that when the returns to fertilizer are high, farmers are willing to expend much time and effort to obtain fertilizer" (Smith et al., 1994, pp. 547-48)." This suggests that the development of output markets and a marketable surplus could logi-

cally precede development of input markets.

A second study informing this issue is a commodity-sector study of Malian maize, conducted as a follow-on to the Malian IA study. A critical factor in many farmers' decisions to adopt maize was a price guarantee from the grain marketing board. When this guarantee was removed, the regional parastatal compensated for a short period but could not maintain price guarantees in the face of uncertain national demand. Limited demand for maize as a staple food means that broad adoption of maize as a cash crop would flood the market, and prices would decline dramatically. Consequently, even though the payback on investment in the Compagnie Malienne pour le Developpement des Textiles (CMDT) maize program is among the highest in the world, the area planted to maize is limited to 90,000 to 120,000 ha. under current output market conditions.

Looking more generally at Malian grain and legume production and markets, Staatz (1989) contends that:

The fact that markets have developed for some general purpose inputs suggests that if markets are missing for other types of inputs, the first hypothesis that should be tested is that, given current relative prices, the input won't pay for itself at the farm level. The policy implication of this hypothesis, if verified, is that efforts should be put first into increasing the productivity of the input rather than trying "artificially" to create a delivery system for which insufficient effective demand exists, unless such a delivery system can substantially reduce the real delivered cost of the inputs to the farmers (p. 16).

Coupling Staatz's argument about input markets with the maize demand constraint suggests that greater emphasis should be placed on output market development as an investment complementary to agricultural TDT. An important complexity is that the key output markets are not always the ones in which technical change occurs. Much of rural Africa is roughly self-sufficient in major food products, with market development limited by very high transport costs. As a result, farmers may not be able to sell the increased output from adopting a higher-yielding foodcrop technology. But if they can sell some other product

whose transport costs are relatively low, they still benefit greatly from adopting the new foodcrop technology. Many farmers in Zimbabwe, for example, use hybrid maize mainly to reduce the land area and effort needed to feed their families, and to increase their production of cotton, groundnuts, sunflower, and other crops. What is most important is output market development in commodities with latent demand, permitting farmers to adjust their mix of activities to take advantage of new opportunities as they arise.

Summarizing the evidence on input and output markets and technology leads to the following hypotheses:

- A functioning output market with reasonably stable and profitable (for farmers) prices is necessary to absorb increases in production of the magnitude associated with agricultural transformation.
- The output marketing structure itself may develop simultaneously with agricultural transformation.
- Guaranteed output markets and prices can provide considerable incentives to farmers, and the supply response is often large.
- Guaranteed output markets and prices for food crops often cannot be maintained in the face of a large supply response: limited domestic demand often means that the guaranteed price amounts to a financially unsustainable subsidy.
- Significant technical change in the absence of price intervention may lead to output price fluctuations.
- Farmers will and have found ways to purchase improved inputs for cash crops.
- The private sector can and has provided input markets in some areas.
- The emergence of a functioning, private-sector input market to provide inputs embodying technical advances, such as high-yielding seeds, may take a decade or longer.
- There is a role for the public sector in maintaining input supply during the development of private markets.

Synthesizing these points suggests that investments complementary to TDT be directed toward develop-

Table 4.2. Summary of On-Going Impact Assessment Studies in Southern Africa

Author(s)	Country	Commodity	Time Period
Ministry of Agriculture, SACCAR, CIMMYT	Tanzania	Maize	1974–2005
DR&SS and SADC/ICRISAT SMIP	Zimbabwe	Pearl millet Sorghum SV2	1987–2005 1981–2005
DR&SS and SACCAR	Zimbabwe	Sunflower, soybeans, and groundnuts	1975–2000
Ministry of Agriculture and SADC/ICRISAT SMIP	Namibia	Pearl millet	1987–2005
Agricultural Research Council and SACCAR	South Africa	Russian wheat aphid control	1980–2005
Agricultural Research Council and SACCAR	South Africa	Lachenalia	1980–2005
Agricultural Research Council and SACCAR	South Africa	Agroforestry	1980–2005

ment of physical and institutional services with public-good characteristics for output markets—that is, services such as market information systems or roads that can be used by large numbers of people at low cost without preventing others from using the same service. Whether or not these hypotheses will hold up under the variety of conditions seen in Africa is an empirical question that merits further efforts.

4.3. CURRENT AND FUTURE DIRECTIONS

4.3.1. Studies Currently Underway

With over 200 African scientists having received at least short-term IA training, it is often difficult to determine exactly what studies are ongoing until the dissemination process begins. The biggest constraints to increasing the use of IA are limited scientist time and operating expenses. It is clear that at least some of the trained scientists are doing some work, often shoestringing a budget together. For example, SACCAR has compiled a list of know, ongoing IAs in Southern Africa (Table 4.2). Seven ex-ante studies are ongoing in three Southern Africa Development Coordinating Committee

(SADCC) countries and South Africa, covering a variety of different agricultural innovations.

4.3.2. Future Directions

Three questions are critical to the future of African agricultural TDT, and indeed critical to the future of African agriculture:

- How do we use the funds we have more efficiently?
- Are current funding levels sufficient?
- If not, how do we get more funds?

Improved TDT efficiency requires institutional innovations in research, extension, and other TDT organizations, and just as importantly, innovations in how these organizations interact with one another. Increased funding is needed so that funding levels are stable and consistent with the level of continuing technological advances needed for agricultural transformation and more rapid economic growth.

4.3.2.1. Institutional Innovations for Improved TDT Efficiency

The IA and a number of other assessments and descriptions of African agricultural TDT institutions

show considerable problems with the institutional paradigms under which these institutions operate. These problems include low salaries, limited or non-existent operating expenses, lack of scientific interactions within and between organizations, lack of financial accountability, lack of accountability for impact, etc. IA is currently considered as part of the solution at least to lack of accountability for impact, and closely related to improved financial accountability (since IA typically records or uses existing information on the cost of the TDT that generates—or fails to generate—impact). Given the current situation, this is appropriate. However, one must be delicate in the use of IA for accountability.

The current situation in African agricultural TDT institutions is largely characterized by undirected research. Scientists do what they can with limited funds, which sometimes even curtail interactions with farmers, or investigate areas of interest to donors. Priority-setting exercises are new, and allocation of resources to African priority areas is hampered by political and institutional processes in addition to the lack of operating funds and fungible support. Integration of social goals and off-farm socioeconomic constraints into research agendas and project selection is superficial. IA can help to draw the links between successful science and positive social change. Knowledge of the links can help TDT institutions to realize greater impact and be more accountable in their generation of impact.

The critical issue is that IA be used to inform individual and institutional decision making from a systems perspective, and not substitute for weighty discussion and consideration. At its worst extreme, IA can lead to hyper-delineation of research projects and activities, so that the researcher is no longer a scientist in quest of knowledge and innovation, but a factotum carrying out a prescribed sequence of activities with little place for thought or ingenuity.

The development path on which TDT institutions and individuals must strive to remain is a happy medium. NARIs must strive to direct TDT activities toward those priority areas expected to generate the greatest social impact, while maintaining enough flexibility to allow scientists to be innovative and entrepreneurial in their activities.

4.3.2.2. Are Current Funding Levels Sufficient?

Current levels of funding for African agricultural research are embarrassingly low. In a sample of 19 sub-Saharan countries, agricultural research expenditures average about 0.8 percent of the value of agricultural production (Pardey, Roseboom, and Beintema, 1995). This is far less than the World Bank's target of 2 percent (which is perhaps best viewed as a minimum level).

In their sample of 19 sub-Saharan countries, Pardey, Roseboom, and Beintema found that real expenditures are growing but the rate of growth is very slow. For the sample, the average annual growth rates of expenditures are 2.6 percent for 1971–1981 and 0.1 percent for 1981–1991. This growth rate in expenditures masks trends indicative of declining use of funds on research—TDT institutions have become employment rather than research centers. The growth rate of researchers was 4.8 percent for 1971–1981 and 2.8 percent for 1981–1991. Expenditures per researcher declined by nearly 15 percent in just five years, from 1986 to 1991. At the same time, the number of support staff per researcher—nearly 10—is exorbitant. As a consequence, personnel expenditures per researcher (salaries) have been declining in real monetary terms but are growing as a share of the budget. Operating expenses have fallen in real monetary terms and as a share of the budget, to about 25 percent of costs for government agencies, or about one-half the usual rule of thumb. The result is TDT institutions that struggle to generate impact. Scientist turnover is high, and scientific research is hampered by the lack of operating expenses. Considerable anecdotal evidence indicates that some institutions lack even the operating funds to pay for a reasonable number of farm visits by research scientists.

Even more embarrassing to African policymakers is the declining importance of agricultural research in African priorities. As a proportion of total government expenditures, from 1971 to 1991 national governments decreased their relative funding for agricultural research by 37 percent (Pardey, Roseboom, and Beintema). The five countries in the sample with incomes between \$750 and \$1,500 (1985

international dollars) and the four countries with incomes in excess of \$1,500 per capita—those countries most able to afford it—showed a decline of nearly two-thirds in the relative level of agricultural research expenditures. In a 23-country sample, Pardey, Roseboom, and Beintema found that donors provided 62 percent of agricultural research and development funding to African countries with per capita incomes of less than \$750/annum, and 32 percent for countries with per capita incomes of \$750 to \$1500. These data clearly show that African governments have chosen not to invest in agricultural research.

The failure of the 1970s and 1980s is not in the performance of African agricultural research; it is in the funding. Agricultural TDT is a good—perhaps even the best—tool for generating long-run, sustainable improvements in income, nutrition, and welfare in agriculturally based economies. To neglect this approach raises serious questions about African and donor commitment to sustainable economic growth.

4.3.2.3. Generating Sufficient Funding for TDT

Activities oriented toward generating funding for TDT, such as work on sustainable financing mechanisms or accountability procedures, have been largely separate from IA activities. To date, this has been appropriate. The primary objectives of early IA studies were to quantify the levels of impacts relative to the costs and to delineate those factors most influencing the impacts or lack thereof. The very real problems of NARIs and NARS notwithstanding, the conclusion to be drawn from the IA studies and examination of funding patterns is that increases in funding for African agricultural TDT are necessary for significant improvement in African welfare. Obtaining such increases will require confidence on the part of the investor—whether it be a national government, producer group, or donor. One way of obtaining such confidence is to provide the investor with a documented record of success and/or lessons learned from past activities that were less successful, and ex-ante IAs showing how these lessons have been incorporated into the proposed project and the impacts to be generated from that project. Consequently, it is

now time that IAs become more intricately linked with financing initiatives.

A second important agenda item for IA in generating funding is distribution, extension, and discussion. Sensitization workshops are one of many ways of doing this successfully. Any and all appropriate methods should be used to facilitate the education of policymakers in the benefits of agricultural TDT. This is a long, expensive, and time-consuming process. But it has to be done. If agriculturally based, African economies are going to develop, agricultural TDT systems will play important roles in the development process. Underfunded TDT systems will not be able to fulfill their needed roles.

4.3.3. Implications for the Technology Impact Assessment Agenda

To date, the IA agenda has been concerned primarily with the mobilization of resources for African agricultural TDT, with important but secondary emphasis on improving the efficiency with which these resources are used. By now it is clear to all who examine the evidence that there is a strong case to be made for continued investment in African agricultural TDT at increasing levels of funding.

Impact assessments have also raised issues related to improved efficiency of technology systems, but has not taken the step to derive actionable recommendations to resolve these issues. This is consistent with the relative emphasis placed on these issues in the bulk of the ROR studies. It is now time to move the IA agenda to making actionable recommendations on improving the efficiency of technology systems. This section describes the type of IA studies needed to accomplish the outcome of actionable recommendations that are based on solid socioeconomic analysis.

4.3.3.1. Institutional Strengthening

Institutional strengthening is needed to improve the efficiency of national, regional, and in some cases international research organizations and systems. Specific recommendations related to IA are made in Chapter 3 of this report. More generally, strengthen-

ing is needed to improve the mobilization and allocation of research resources by African technology systems.

The specific strengthening actions needed will depend in individual circumstances, but a start can be made by synthesizing information from institution and project reports, many of which are available in Washington D.C. Follow-up with directors general of NARIs and with NARI stakeholders is critical. The type of follow-up will depend largely on each director general's specific circumstances, and the resulting actions are in many cases likely to be oriented towards managerial actions rather than part of IA of existing or potential techniques. USAID may wish to make available to NARI directors general upon their request technical assistance from a team of research management specialists to improve management mechanisms. Some of this is in place in the form of technical assistance for financial accountability. The point here is to extend this assistance to help NARIs delineate administrative mechanisms for reallocating financial and human resources to those areas and priorities that are expected to generate the greatest social benefit.

4.3.3.2. Sequencing the Research Agenda for Resource-Poor Areas

The interface between innovative natural resource management techniques and traditional agricultural innovations aimed at increasing on-farm productivity is especially critical in resource-poor areas. Appropriate sequencing of complementary innovations is crucial for significant and sustainable improvements in the welfare of the people living in these areas. There is no single "right" sequence. Each area has its own specific needs and opportunities, and there may be no "right" sequence even for a small area. The key is that location-specific investigations can identify where the greatest complementarities between natural resource and agricultural productivity TDT lie. Impact assessments to date clearly indicate that such complementarities generally exist, but that they may take very different forms in different local areas. The joint research agenda for NRM and agriculture can then be built around these complementarities.

In West Africa, the historical method for improving semiarid regions is to introduce shorter season millet and sorghum cultivars and thereby obtain drought escape. This is a portfolio strategy, which reduces risk and increases incomes in low rainfall years. However, in adequate and good rainfall conditions, these cultivars are not able to take advantage of the improved conditions and often suffer more than local longer-season cultivars from insects and disease. Stem borers, head bugs, mold, and bird damage have all been documented to attack especially hard early cultivars of millet and sorghum. Hence, to increase income in these semiarid regions, more attention to water harvesting and to increasing soil fertility—most likely through increased application of organic and inorganic fertilizers—is necessary. Then, medium and longer season cultivars can take advantage of the improved agronomic environment.

In East and Southern Africa, drought escape also takes the form of short-cycle, high-yielding maize varieties that in some cases have replaced millet and sorghum in drier areas. The development strategy in these areas differs from that in arid and semiarid West Africa because of the potential of yields up to 6 t/ha obtained with short-cycle maize—up to six times the level obtained with local varieties under low-input conditions. The important NRM question in these areas is the stability and sustainability of the various maize farming systems and practices, particularly in areas with fragile soils having the potential for degradation, fertility loss and erosion under poor management conditions.

In the hilly areas of Africa, terraces, bunds, and vegetative barriers prevent erosion from washing the farm into the valley. The traditional methods of constructing these barriers tend to be very labor intensive and are done only by farmers with very low opportunity costs. However, once these investments are made, there is substantial potential in the new agricultural system. These investments make possible the use of more intensive production methods (inorganic fertilizers) and more valuable crops. Again it is necessary to be selective about where public policy facilitates this technical change, as not all hillsides are capable of sustainably producing marketable surpluses.

Despite the regional generalizations made above, the critical issue remains that the portfolio of NRM, agricultural production, and postproduction innovations needs to be tailored to the local agroclimatic and socioeconomic conditions. Moreover, there is no guarantee that a successful portfolio can be found for very low rainfall and poor soil quality areas. Finally, it is important to reiterate that in such areas, the goal of investment in research and technology transfer may be sustainable alleviation of rural poverty, rather than agricultural transformation.

4.3.3.3. Public-Sector Investment in Research for Smallholders

Since independence, most African NARIs have reoriented their research agendas less towards commercial farms and more towards smallholders. This has resulted in a number of technical innovations and agronomic recommendations directed toward smallholder, low-input farming systems. Since NARIs are supported by public-sector funds—either from donors or from national government—this reorientation is appropriate and worth intensifying. Impact assessments often focus on the effects of technical innovations on smallholders but rarely make the link between increases in smallholder productivity and aggregate agricultural growth. If the goal of agricultural TDT is agricultural transformation, then a better understanding of how smallholders can be released from the constraints of subsistence farming and become involved in farming as a way of generating both food and cash income, and of how TDT can facilitate this process, is critical to determining how best to formulate the smallholder research agenda. Impact assessments that measure impacts both at the farm level and the translation of these farm-level effects to faster national growth rates can provide important information on this issue.

4.3.3.4. Markets, Trade, and Growth

For smallholders and large commercial farmers alike, the IAs have shown that output markets are most likely the primary determinant of the aggregate impact of innovative techniques. That is, agricultural innovations that are successful in improving the welfare of farmers

are likely to generate broad-based social improvements through lower food prices, higher food quantities, and improved food access if the innovations are applied to agricultural outputs that have or can develop a large market. Innovations in niche crops may be remunerative but are unlikely to stimulate agricultural transformation. Innovations in basic food and fiber crops or major export crops have the potential to ignite the transformation of the agricultural system and thereby benefit much of the population. It is these innovations that are most likely to raise agricultural and economic growth rates measurably.

In an era of structural adjustment and market liberalization, trade becomes a key determinant of potential market size. Interesting theoretical models of the relationships among trade, technical innovation, market size, returns to research, and growth include Dinopoulos, Oehmke, and Segerstrom, 1993; Oehmke, 1995; and Dinopoulos and Oehmke, 1997. Yet these models provide little in the way of application. Block (1994) has examined the relationship between agricultural innovation and agricultural and economic growth in an African context, but lacks the theoretical foundations to make strong actionable recommendations.

There are two critical questions to be answered:

- How do African agricultural research organizations incorporate emerging output market and trade regimes into their research planning and resource allocation? and
- What trade and output market investments or policies are most complementary to agricultural innovation in stimulating broad-based economic growth?

The answers to these questions will be region, country, and commodity specific, but are the essence of actionable statements.

4.3.4. The Impact Assessment Agenda

Summarizing the above discussion leads to a technical agenda for impact assessment with five major items:

- *Impact assessments that quantify the economic benefits and costs of TDT as part of the agenda*

to mobilize additional resources for TDT. These studies should include both ex-post studies to document the impacts of past investments and what factors have influenced the type and magnitude of impact, and ex-ante studies that provide information to predict the adoption, income, and price effects of potential innovations either recently introduced or still in the development and testing stage. Lessons from the studies help to define priority areas for research and to achieve the greatest impact from developed and released innovations. Results and lessons learned should be extended to national governments and donors as they make decisions about the mobilization of funds for agriculture and agricultural TDT.

- *Impact assessments that develop and test improved methods for incorporating a full range of social benefits and costs, including the impacts on the stability and sustainability of present and potential agricultural practices and innovations; the distribution of benefits among different groups in society, particularly the poor and other disadvantaged groups; and the impacts on the welfare of individual family members, especially women and children.* Traditional benefit measures focus on increases in farm incomes and reductions in the price of food to consumers. These studies use recently developed or new methods to include relevant considerations such as environmental sustainability, as well as to focus on particular impacts in particular groups, such as how child nutrition is enhanced by greater availability of more affordable food. Lessons from these studies are crucial to more effective allocation and prioritization of TDT and complementary funds.
- *Assessments of complementary factors contributing to impact.* Even though agricultural TDT is necessary for achieving social goals such as poverty alleviation in Africa, TDT cannot succeed by itself. With the emergence of Africa from structural adjustment, devaluation, the enfranchisement of the majority in South Africa, privatization, etc., opportunities for making investments complementary to TDT abound. These studies investigate such opportunities, focusing on input and output market development and evolution, price stability for agricultural products, infrastructure development, and new product development and promotion. The studies would adapt to TDT assessment methods developed elsewhere for evaluating the performance of the other factors, most notably simulation and projection of market evolution and new product utilization, and commodity sector analysis of existing markets. Lessons from these assessments will help TDT systems respond to the changing policies and economics, and conversely will inform complementary investments to translate farm-level productivity increases into broad improvement in individual welfare.
- *Assessment of institutional impacts to help understand the links from institutional innovation in agricultural TDT systems to improved quantity and quality of innovations released to increased adoption and use of these innovations to greater social benefits.* These studies analyze the interfaces between management capacity, institutional culture, and socioeconomic impact. Due to the complexity of the interfaces, these studies will be more costly than other types of IA, but conducting a few of these studies as in-depth components of ex-post and ex-ante IA is fundamental to improve the vitality of TDT organizations. They can build on the conceptual and empirical advances of incorporating sustainability and gender issues. Lessons from these assessments are used to guide strengthening processes for TDT institutions and systems to achieve more efficient use of funds and greater impact.
- *Impact assessments that verify the links between innovation at the farm or micro level, and improved macro-economic performance.* Previous neglect of the apparent inconsistency between high RORs and poor aggregate performance has hampered the mobilization of TDT funds. These studies provide needed conceptual and applied work on assessment of the contributions of agricultural TDT to sectoral objectives such as sustainable agricultural transformation and to social goals such as growth in per capita income, poverty alleviation,

and food security. Within this thrust, emphasis is placed on assessments of the impact of agricultural TDT on social objectives via the mechanisms of agricultural trade and agricultural growth, considering the expanding opportunities for regional trade and the emergence of regional platforms for TDT. Lessons from these assessments will inform the allocation of national and regional resources to enhance trade and growth.

Studies conducted in the context of the first item should be carried out primarily by African institutions. Donors should support as appropriate requests for backstopping, operating funds, methodological development, and broad dissemination of results. Donors should also support administrative mechanism that can respond quickly to requests for short-term technical assistance, perhaps by drawing on a wide pool of scientists or consultants with complementary and to some degree overlapping skills, so that the appropriate skill can be accessed in a timely fashion. This pool should increasingly include African researchers trained in IA.

The second and third items require a combination of theoretical and methodological development, empirical application and validation, and dissemination and use of results as an integral part of research planning and implementation. The obvious interactions and synergies between these two items suggests that a single mechanism be used to coordinate work in these areas. The studies themselves could be conducted by a group which might include one or more representatives of

U.S. universities, African universities, and African TDT systems. Theoretical and methodological development would take place at universities, with participation of and some long-term training of NARS scientists. Application and validation would take place within the TDT system, with intellectual support and assistance from the universities. Directors general of NARIs and chief executive officers of other institutions in the TDT systems should help to coordinate the application in a manner that informs those questions and issues that will most influence their resource allocation decisions.

The fourth and fifth items also exhibit a great deal of complementarity, with institutional innovations needed not just to make TDT systems more responsive to farmer needs, but to improve their contribution to the achievement of broader social goals and objectives. This again suggests a single coordinating mechanism or investigator for these two items. The fourth item is very institution specific, and investigation into potential innovation should be led by an African university that has good links both with the TDT system in its country or region, and with U.S. universities for backstopping, at the request of the NARI, RARI, other other institution in the TDT system. The fifth item requires methodological development and empirical application and validation. It is best carried out by an investigative team the includes U.S. and African faculty, scientists and researchers representing universities and NARS. Dissemination of results should target donors and NARS, including representatives from Ministries of Agriculture, Trade, and other senior government officials most directly responsible for the achievement of broad social goals.

5. Conclusions

The past seven years have witnessed the emergence of a considerable literature on the impacts of African agricultural technology development and transfer (TDT). This document, evolving from two days of roundtable discussions with many of the key contributors to this literature, reviews and synthesizes this literature. Several striking conclusions can be drawn:

1. No agricultural economy has developed in the absence of technical innovation in agriculture.

The implication is straightforward: African agricultural TDT is a necessary component of African development.

2. African agricultural TDT has had impact across a variety of countries, commodities, and agroclimatic conditions.

This conclusion contradicts the conventional wisdom that African agricultural, and ergo African agricultural TDT, has failed. It is based on the three findings:

- *A rate-of-return (ROR) calculation based on social-surplus measurement of benefits is an appropriate single measure of the impacts of agricultural TDT relative to the costs of investment.* ROR calculations with benefits based on improvements in social surplus are the primary measure used in quantifying impacts relative to costs. The ROR is an appropriate choice for summarizing the benefits and costs and their distribution over time. The benefits included in social surplus measures include impacts on household welfare such as improved nutritional status and enhanced food security from greater food production and productivity. But the greatest effect of increased agricultural productivity, particularly among the poorest of the poor, is an increased ability to reallocate labor and/or cash

income away from food production or purchase and toward the purchase of nonagricultural items—health care, sanitation, improved housing, schooling for children, and the like. The social surplus measure is specifically designed to approximate for the impact of increases in agricultural productivity on the entire spectrum of household welfare improvements.

- *ROR studies show that African agricultural TDT has had impact.* An ROR that is in excess of the opportunity cost of generating the funds supporting the underlying TDT—typically considered to be in the 2 to 15 percent (inflation adjusted) range—provides an economic justification for the investments. The RORs to investments in African agricultural TDT usually exceed 15 percent, across a variety of countries, commodities, and agroclimatic conditions. This provides substantive and quantitative evidence that investments in African agricultural TDT have generated impact and improved household welfare. Ex-ante studies indicate that similar impacts will be generated by current TDT activities.

- *Aggregate evidence suggests that the conventional, pessimistic view of African agricultural failure is overstated.* A review of the aggregate evidence, such as trends in food production, shows that, even though agricultural performance was poor in the 1970s and 1980s, there are varied causes: isolationism, poor agricultural policy environment, scattered droughts, unrealistic expectation, reorientation toward the African smallholder, etc. More importantly, performance seems to have improved considerably in the 1990s. The improved performance is exemplified in more rapid increases in total food production and productivity, and increases in food production per capita.

3. There is institutional failure in African national agricultural TDT systems: symptomatic of this failure is the inability to mobilize and organize national resources for TDT.

The fact that impacts have been generated means neither that the impacts have been generated in the most efficient manner, nor that they impacts are as large or positive as they could be. Impact studies show that African agricultural TDT institutions and systems can make considerable improvements in effectiveness and efficiency. Most notably, available funds are used poorly and are inadequate. The two problems feed off each other. If available funds are insufficient to stimulate the magnitude of changes desired for agricultural transformation, development, and economic growth, then funded programs necessarily have smaller impacts than those expected of them. Poor allocation of existing funds—exemplified by low salaries, a lack of operating expenses, and failure to allocate resources in accord with rationally established development priorities—will give national governments and donors pause when considering whether to invest additional monies. TDT institutions have been slow to recognize and remedy their own shortcomings, not trusting policymakers to continue funding if problems are admitted. It is imperative for broad-based agricultural growth that African agricultural TDT institutions put their houses in order, so that they are capable of accountably and efficiently handling current and increased levels of funding.

4. African national governments have failed to invest adequate levels of resources in agricultural TDT.

Agriculturally led development and technological progress in agriculture is not part of the national agenda for any African country reviewed. Rhetoric about agricultural and economic growth notwithstanding, national funding for African agricultural TDT is poor and getting worse. There is by now a well-trained cadre of African economists cognizant

of the basics and nuances of the economic development process. Heads of state, ministers of agriculture and finance, and other policymakers have not listened to their own economists. The failure to invest adequate levels of resources in agricultural TDT is a failure to incorporate agricultural development as a meaningful component of the national agenda.

5. Agricultural TDT is critical to the future of broad-based improvements in the welfare of African people.

Africa is on a cusp. Over the past two decades, large numbers of African agricultural scientists have been trained, and some countries have institutionalized university programs with the ability to train enough scientists to meet national needs. Following structural adjustment programs, there is significant opportunity to stimulate agricultural transformation and broad-based economic growth. By increasing both the efficiency with which TDT funds are used and the magnitude of the funds available, African governments can take a critical step towards an agricultural and economic transformation that significantly improves the welfare of commercial farmers, smallholders, and urban consumers. By failing to invest adequately in agricultural TDT, African governments have failed to make an investment necessary for transformation. Seeing this government failure to provide adequate levels of TDT, large-scale commercial farmers are more and more turning to contracted or privatized research. The African smallholder is too poor to participate in these activities and must rely on public TDT. Inadequate funding for public TDT means that the smallholder will not be able to keep up. The scenario is unappealing: large-scale commercial farmers will be increasingly competitive internationally and will reap the benefits of agriculture, but the smallholder—the majority of African farmers—will remain poor in the next century. The options are clear: it is now up to African governments to implement their vision for 21st-century Africa.

References

- Abidogun, A., 1982. "Cocoa Research in Nigeria: An Ex-Post Investment Analysis." *The Nigerian Journal of Economic and Social Studies*. pp. 21–35.
- Aghib, Anthony, and Jess Lowenberg-DeBoer. N.d. "The Regional Impact of Collaborative Research and Extension Programs: The Case of Striga Resistant Sorghum Varieties Developed by INTSORMIL." Mimeo, Purdue University.
- Ahmed, Mohamed M., William A. Masters, and John H. Sanders. 1995. "Returns to Research in Economies with Policy Distortions: Hybrid Sorghum in Sudan." *Agricultural Economics*, 12:183–192.
- Akgungor, Sedef, David Makanda, James Oehmke, Robert Myers, and Young Choe. 1996. "A Dynamic Analysis of Kenyan Wheat Research and Rate of Return." *Proceedings of the Conference on Global Agricultural Science Policy in the 21st Century*, Melbourne.
- Anandajayasekeram, P., and D. R. Martella. 1995. "Institutionalization of Impact Assessment: SACCAR's Experience in Southern Africa." Paper presented at USAID Collaborative Workshop on Agricultural Technology Development and Transfer in Sub-Saharan Africa, Harare, Zimbabwe, January 24–27, 1995.
- Anandajayasekeram, P., D. R. Martella, J. Sanders, and B. Kupfuma. 1995. *Report on the Impact Assessment of the SADC/ICRISAT Sorghum and Millet Improvement Program*. SADC/SACCAR.
- Anandajayasekeram, P., and D. R. Martella. 1996. "Impact Assessment of Agricultural Research and Extension in East, Central, and Southern Africa." To be published in *The Zimbabwe Journal of Agricultural Research*, Department of Research and Specialist Services, Ministry of Lands, Agriculture, and Water Development, Causeway, Zimbabwe (forthcoming).
- R.B. Austin. 1985. "Some Crop Characteristics of Wheat and Their Influence on Yield and Water Use." In J. D. Srivastava, E. Porceddu, E. Acevedo, and S. Varma, eds. *Drought Tolerance in Winter Cereals*. Proceedings of an International Workshop, 27–31 October, Capri, Italy. Chichester, Eng.: John Wiley and Sons. pp. 321–38.
- Baker, F. W. G. 1989. "Evaluation of Traits for the Improvement of Water Use Efficiency and Harvest Index." In N. C. Turner, M. E. Nicolas, K. T. Hubick, and G. D. Farguhar. *Drought Resistance in Cereals*. Wallingford: ICSU Press / CAB International. pp. 177–90.
- Batie, Sandra and Daniel Taylor. 1991. "Assessing the Character of Agricultural Production Systems: Issues and Implications." *American Journal of Alternative Agriculture*, 6:184–87.
- Bertelsen, M., and S. Ouedraogo. N.d. "The Value of Research on Indigenous Knowledge: Preliminary Evidence from the Case of Zai in Burkina Faso." Mimeo, Purdue University.
- Bingen, R. James, A. E. Hall, and Mbaye Ndoye. 1988. "California Cowpeas and Food Policy in Senegal." *World Development*, 16:857–65.
- Bingen, R. James, and Brent Simpson. 1996. "Technology Transfer and Agricultural Development in West Africa: Institutional Challenges and Opportunities in Mali." In Yong S. Lee, ed. *Technology Transfer and Public Policy*. Forthcoming. Greenwood Press.
- Block, Steven A. 1994. "A New View of Agricultural Productivity in Sub-Saharan Africa." *American Journal of Agricultural Economics*, 76:619–626.
- Boughton, Duncan and Bruno Henry de Frahan. 1994. *Agricultural Research Impact Assessment: The Case of Maize Technology Adoption in Southern Mali*. International Development Working Paper No. 41. Michigan State University, East Lansing, Michigan.
- Boughton, Duncan. 1995. "A Commodity Subsector Approach to the Design of Agricultural Research: The Case of Maize in Mali." Ph.D. Dissertation. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Boughton, Duncan, Eric Crawford, Julie Howard, James Oehmke, James Shaffer, and John Staatz. 1995. *A Strategic Planning Approach to Agricultural*

- tural Research Program Planning in Sub-Saharan Africa*. International Development Working Paper No. 49. Michigan State University, East Lansing, Michigan.
- Byerlee, Derek and Paule Heissey. 1996. "Past and Potential Impacts of Maize Research in Sub-Saharan Africa: A Critical Assessment." *Food Policy*. 21:255–77.
- Byerlee, Derek, and Carl K. Eicher. 1997. *Africa's Emerging Maize Revolution*. Boulder: Lynne Rienner Publishers.
- Chisi, M., P. Anandajayasekeram, D. Martella, M. Ahmed, and M. Mwape. 1997. *Impact Assessment of Sorghum Research in Zambia*. SACCAR, Botswana.
- Clay, D., T. Reardon, and J. Kangasniemi. 1997. "Sustainable Intensification on the Highland Tropics: Rwandan Farmers' Investments in Land Conservation and Soil Fertility." *Economic Development and Cultural Change*. Forthcoming.
- Dalton, Timothy, and William A. Masters. 1997. "Soil Degradation, Technical Change, and Government Policies in Southern Mali." Paper submitted for presentation as a Selected Paper at annual meeting of the American Agricultural Economics Association, Toronto, Ontario, Canada, July 27–30.
- Demeke, Mulat, Ali Said, and T. S. Jayne. 1996. "Relationships between Grain Market Performance and Fertilizer Markets and Profitability." Paper presented at the Grain Market Research Project Discussion Forum, November 8–9, 1996, Sodere, Ethiopia. Mimeo, Department of Agricultural Economics, Michigan State University.
- Dioné, Josué. 1989. "Informing Food Security Policy in Mali: Interactions Between Technology, Institutions, and Market Reforms." Ph.D. dissertation, Michigan State University, East Lansing, Michigan.
- Dinopoulos, Elias. 1966. *Agricultural R&D and Economic Growth*. International Development Paper No. 60. Michigan State University, East Lansing, Michigan.
- Dinopoulos, Elias, and James F. Oehmke, 1997. "A Neo-Schumpeterian Model of Agricultural Innovation and Growth." Staff Paper No. 97-18. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Dinopoulos, Oehmke and Segerstrom. 1993. "High-Technology Industry Trade and Investment: The Role of Factor Endowments." *Journal of International Economics*, 34:49–71.
- Evenson, R.E. 1987. "The International Agricultural Research Centers: Their Impact on Spending for National Agricultural Research and Extension." CGIAR Study Paper No. 22. Washington, D.C.: The World Bank.
- Ewell, Peter. 1992. "The PRAPACE Network: CIP-NARS Collaboration for Sustainable Agricultural Production in Africa." Paper presented at the Symposium on the Impact of Technology on Agricultural Transformation in Sub-Saharan Africa, Washington, D.C.
- Falcon, Walter P. 1970. "The Green Revolution: Generations of Problems." *American Journal of Agricultural Economics*, 52(5): 698–712.
- Fisher, Monica G., Abdoulaye Fall, and Mamadou Sidibe. 1995. "The Impact of Rice Research in the Senegal River Valley." Mimeo. Dakar, Senegal: ISRA/BAME.
- Gilbert, Elon, Lucie Phillips, William Roberts, Marie-Therese Sarch, Melinda Smale, and Ann Stroud. 1994. *Maize Research Impact in Africa: The Obscured Revolution—Complete Report*. SD Technical Paper No. 7. Washington, D.C.: U.S. Agency for International Development / Bureau for Africa / Office of Sustainable Development.
- Hayami, Yujiro, and Vernon Ruttan. 1985. *Agricultural Development: An International Perspective*. Baltimore: Johns Hopkins University Press.
- Henry de Frahan, B., C. Youssouf, S. Traore, and M.B. Diarra. 1989. *Feasibility Study for the Expansion of the Farming Systems Research Division in the Fifth Region of Mali*. Bamako: Ministère de l'Agriculture and Michigan State University.
- Howard, Julie, George Chitalu, and Sylvester Kalonge. 1993. "The Impact of Investments in Maize Research and Dissemination in Zambia. Part I: Main Report." International Development Working Paper No 39/1, Michigan State University, East Lansing, Michigan.
- Howard, Julie Ann. 1994. "The Economic Impact of Improved Maize Varieties in Zambia." Ph.D. Dissertation, Department of Agricultural Econom-

- ics, Michigan State University, East Lansing, Michigan.
- Huffman, Wallace E., and Robert E. Evenson. 1993. *Science for Agriculture*. Ames: Iowa State University Press.
- Isinika, A.C. 1995. "Assessing the Effect of Agricultural Research Expenditures on Agricultural Productivity in Tanzania." Ph.D. dissertation, University of Kentucky, Lexington, Kentucky.
- Johnston, Bruce F. and John W. Mellor, 1961. The role of agriculture in economic development. *American Economic Review* 51:566–93.
- Karanja, Daniel D. 1990. "The Rate of Return to Maize Research in Kenya: 1955–88." M.S. Thesis, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Khatri, Yougesh, Colin Thirtle, and Johan van Zyl. 1995. "South African Agricultural Competitiveness: A Profit Function Approach to the Effects of Policy and Technology." In G.H. Peters and D. Hedley, eds., *Agricultural Competitiveness: Market Forces and Policy Choice*. Proceedings of the 22nd International Conference of Agricultural Economists, Harare, Zimbabwe.
- Kupfuma, Bernard. 1994. "The Payoffs to Hybrid Maize Research in Zimbabwe: An Economic and Institutional Analysis." M.S. Thesis, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Kuyvenhove, A., J. A. Becht, and R. Ruben. 1996. "Public Investment for Soil Improvement in West Africa: Economic Criteria for Phosphate Rock Use to Enhance Soil Fertility Management." Mimeo, Public Goods and Services Project, Wageningen Agricultural University (Wageningen, The Netherlands).
- Laker-Ojok, Rita. 1992. "The Rate of Return to Agricultural Research in Uganda: The Case of Oilseeds and Maize." International Development Working Paper No. 42, Michigan State University, East Lansing, Michigan.
- Le Houérou, H.N., G.F. Popov, and L. See. 1993. *Agro-bioclimatic Classification of Africa*. Agrometeorological Series Working Paper No. 6. Rome: Food and Agriculture Organization.
- Lilja, Nina, and John H. Sanders. 1997. "Welfare Impacts of Technological Change on Women in Mali." Paper to be presented at annual convention of International Association of Agricultural Economists, Sacramento, California, August 10–16.
- Macmillan, J., G. Mudimu, J. MacRobert, L. Rugube, E. Guveya, L. Mutemeri, and K. Chanakanyuka. 1991. "Ex Ante B/C Analysis of Small Farm Maize Research Demonstrations, Zimbabwe." Working Paper, Department of Agricultural Economics and Extension, University of Zimbabwe.
- Makanda, David W., and James F. Oehmke. 1996. "The History of and Returns to Kenya Wheat Research." Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Makau, B.F. 1984. "Measurement of Economic Returns to Wheat Research in Kenya." Unpublished M.A. Thesis, University of Nairobi, Kenya.
- Makanda, D.W., and J.F. Oehmke. 1996. "The History of and Returns to Kenya Wheat Research." Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Maredia, Mywish K. 1993. "The Economics of the International Transfer of Wheat Varieties." Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Maredia, Mywish K., and Derek Byerlee. 1996. "Determining the Efficiency of Research in the Presence of International Spillovers: Wheat Research in Developing Countries." Mimeo, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Maredia, Mywish K., Duncan Boughton, Julie A. Howard, Daniel D. Karanja, Marie-Hélène Collion, Oumar Niangado, and Touba Bedingar. 1996. "No Shortcuts to Progress: Case Studies of the Status and Impact of Strategic Agricultural Research Planning in Africa." International Development Working Paper, Michigan State University, East Lansing, Michigan.
- Masters, William A. 1994. *Government and Agriculture in Zimbabwe*. Westport, Conn.: Praeger.
- Masters, William A., Touba Bedingar, and James F. Oehmke. 1996. "The Impact of Agricultural Re-

- search in Africa: Aggregate and Case Study Evidence.” Mimeo, Department of Agricultural Economics, Purdue University, West Lafayette, Indiana.
- Mazzucato, Valentina. 1992. “Non-Research Policy Effects on the Rate of Return to Maize Research in Kenya: 1955–88.” M.S. Thesis, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Mazzucato, Valentina, and Samba Ly. 1994. “An Economic Analysis of Research and Technology Transfer of Millet, Sorghum and Cowpeas in Niger.” The Hague, Netherlands: ISNAR / East Lansing, Mich.: Michigan State University.
- Mellor, John W. 1990. “Food Price Policy and Income Distribution in Low-Income Countries.” In C. K. Eicher and J. M. Staatz, eds., *Agricultural Development in the Third World*. 2d ed. Baltimore: Johns Hopkins University Press.
- Mudhara, M., P. Anandajayasekeram, B. Kupfuma, and E. Mazhangara. 1995. Impact Assessment of Cotton Research and Enabling Environment in Zimbabwe, 1970–1995. SACCAR, Botswana.
- Nicholson, S.E., Jeeyong Kim, and J. Hoopingarner. 1988. *Atlas of African Rainfall and Its Inter-Annual Variability*. Department of Meteorology, Florida State University, Tallahassee, Florida.
- Norgaard, Richard B. 1988. “The Biological Control of Cassava Mealybug in Africa.” *American Journal of Agricultural Economics*, 70:366–71.
- Nyaribo-Roberts, F. 1992. “Improving Research Design through Social Science Evaluation.” Paper presented at the Symposium on the Impact of Technology in Sub-Saharan Africa, Washington, D.C. October 14–16, 1992.
- Oehmke, James F., Lisa Daniels, Julie Howard, Mywish Maredia, and Rick Bernsten. 1991. “The Impact of Agricultural Research: A Review of the Ex-Post Assessment Literature with Implications for Africa.” Mimeo, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Oehmke, J. 1995. “Issues of Agricultural Technology Development and Diffusion: A Synthesis of the Literature.” Staff Paper No. 95-58. Department of Agricultural Economics, Michigan State University, East Lansing Michigan.
- Oehmke, James F. 1996. “Technology Frontiers: The Subsector Approach to Analysis of Agricultural Research Impacts.” Project Report. USAID/AFR/SD/PSGE/TDT.
- Oehmke, James F. 1997. “Investments in Agricultural Technology Development and Diffusion.” In Donald McClelland and Luther Tweeten, eds. Forthcoming. *Investment in Agriculture*. Praeger Press.
- Oehmke, James F., and William A. Masters. 1997. “The Impacts of and Returns to African Agricultural Research.” Mimeo, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Ouedraogo, Souleymane, Laraba Ily, and François Lompo. 1995. “Evaluation de l’Impact Economique de la Recherche et la Vulgarisation Agricole: Cas du Maïs dans l’Ouest du Burkina Faso.” Mimeo, INERA, Ougadougou, Burkina Faso.
- Ouedraogo, Souleymane, and Laraba Ily. 1996. “Evaluation de l’Impact Economique des Cordons Pierreux: Cas du Plateau Central au Burkina Faso.” Mimeo, INERA, Ougadougou, Burkina Faso.
- Pardey, Philip G., Johannes Roseboom, and Nienke Beintema. 1995. “Investments in African Agricultural Research.” EPTD Discussion Paper No. 14, International Food Policy Research Institute, Washington, D.C.
- Rohrbach, David D. 1988. “The Growth of Smallholder Maize Production in Zimbabwe: Causes and Implications for Food Security.” Ph.D. dissertation, Department of Agricultural Economics, Michigan State University: East Lansing, Michigan.
- Rukuni, Mandivamba, and Carl K. Eicher. 1994. *Zimbabwe’s Agricultural Revolution*. Mount Pleasant, Harare, Zimbabwe: University of Zimbabwe Publications.
- Rukuni, M. 1996. “A framework for crafting demand-driven national agricultural research institutions in southern Africa.” Department of Agricultural Economics, Staff Paper 96-76. Michigan State University.
- Ruttan, V. 1987. *Agricultural Research Policy*. Minneapolis: University of Minnesota Press.

- Sachs, J.D., and A.M. Warner. 1996. "Sources of Slow Growth in African Economies." Development Discussion Paper No. 545. Harvard Institute for International Development, Harvard University, July.
- Sanders, John H. 1994. "Economic Impact of the Commodity Research Networks of SAFGRAD." In John H. Sanders, Taye Bezuneh, and Alan C. Schroeder, eds. *Impact Assessment of the SAFGRAD Commodity Networks*. Washington, D.C.: USAID/Africa Bureau.
- Sanders, John H., Barry Shapiro, and Sunder Ramaswamy. 1996. *The Economics of Agricultural Technology in Semi-Arid Sub-Saharan Africa*. Baltimore: Johns Hopkins University Press.
- Schultz, T. W. 1980. "Nobel lecture: The Economics of Being Poor." *Journal of Political Economy*, 88:639–51.
- Schwartz, Lisa A., and James F. Oehmke. 1990. "Applying a Benefit/Cost Approach or Rate of Return Analysis to Specific CRSP Projects." Paper presented at the CRSP Conference, Michigan State University, East Lansing, Michigan. Mimeo, Department of Agricultural Economics, Michigan State University.
- Schwartz, Lisa A., James A. Sterns, and James F. Oehmke. 1992. "Economic Returns to Cowpea Research, Extension and Input Distribution in Senegal." *Agricultural Economics*, 8:161–71.
- Schwartz, L., J.A. Sterns, and J.F. Oehmke. 1993. "Economic Returns to Cowpea Research, Extension, and Input Distribution in Senegal." *Agricultural Economics*, 8:161–171.
- Seck, Papa Abdoulaye, Mamadou Sidibé, and Amadou M. Béye. 1995. "Impact Social de la Recherche et du Transfer du Technologies sur le Coton au Senegal." Mimeo.
- Seidi, S. 1996. "An Economic Analysis of Rice Research, Extension, and Seed Production in Guinea-Bissau: Preliminary Evidence from the Case of Swamp Mangrove Rice." Preliminary report to Rice Economics Task Force of the West African Rice Development Association, Bissau, Guinea-Bissau.
- Shapiro, B. I., J. H. Sanders, K. C. Reddy, and T. G. Baker. 1993. "Evaluating and Adapting New Technologies in a High-Risk Agricultural System—Niger." *Agricultural Systems* 42:153–71.
- Smale, Melinda and Paul Heissey. 1994. "Maize Research in Malawi Revisited: An Emerging Success Story?" *Journal of International Development*.
- Smith, Joyotee, Anthony Barau, Abraham Goldman, and James Mareck. 1994. "The Role of Technology in Agricultural Intensification: The Evolution of Maize Production in the Northern Guinea Savanna of Nigeria." *Economic Development and Cultural Change*, 537–54.
- Staatz, John M. 1989. *The Role of Market Conditions in Influencing the Adoption of New Agricultural Technologies in Mali*. Staff Paper No. 89-109. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Sterns, James, James Oehmke, and Lisa Schwartz. 1993. "Returns to Education: The Impacts of MSU Training on West African Scientists." Agricultural Economics Report No. 567. Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.
- Sterns, J.A., and R. Bernsten. 1994. "Assessing the Impact of Cowpea and Sorghum Research and Extension: Lessons Learned in Northern Cameroon." International Development Working Paper No. 43, Michigan State University, East Lansing, Michigan.
- Timmer, C. Peter. 1990. "The Agricultural Transformation." In C. K. Eicher and J. M. Staatz, eds. *Agricultural Development in the Third World*. 2d ed. Baltimore: Johns Hopkins University Press.
- Timmer, C. Peter. 1993. "Why Markets and Politics Undervalue the Role of Agriculture in Economic Development." Hibbard Memorial Lecture Series, Department of Agricultural Economics, University of Wisconsin-Madison.
- Tre, Jean-Philippe. 1995. "The Rates of Return to Mangrove Rice Research in West Africa." Unpublished M.S. Thesis, Purdue University, West Lafayette, Indiana.
- Tripp, Robert. 1993. "Invisible Hands, Indigenous Knowledge and Inevitable Fads: Challenges to

- Public Sector Agricultural Research in Ghana,” *World Development*, 21:2003–16.
- van der Pool, Floria. 1991. *Soil Mining: An Unseen Contributor to Farm Income in Southern Mali*. Amsterdam: Royal Tropical Institute.
- Weber, Michael T., J. M. Staatz, J. S. Holtzman, E. W. Crawford, and R. H. Bernstein. 1988. “Informing Food Security Decisions in Africa: Empirical Analysis and Policy Dialogue.” *American Journal of Agricultural Economics*, 1044–52.

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