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Maize Research Impact in Africa: The Obscured Revolution

Summary Report

Elon Gilbert, Lucie Phillips, William Roberts, Marie-Therese Sarch, Melinda Smale, and Ann Stroud
with
Edgar Hunting

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Productive Sector Growth and Environment Division
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Foreword

The study *Maize Research Impact In Africa: The Obscured Revolution* was started in 1990 as part of the an initiative of the U.S. Agency for International Development (USAID) Africa Bureau to improve its accountability for development change resulting from investments in agricultural technology development and transfer (TDT). The findings presented in this study broaden our knowledge of the impact investments have made and provide useful lessons regarding analytical tools available for progress monitoring and impact assessment of agricultural TDT activities.

The concern for development impact from investments in agriculture in Africa has increased in the four years since this study began. In the future, the concern for impact will be a fundamental issue guiding the choice of development investments. This early effort in examining the impact of research in Africa began at a time when there was little factual evidence on impact of TDT in Africa, but it will play an important role in guiding future progress-monitoring and impact-assessment activities.

The findings of this study, of which this *Summary Report* concisely presents, will be especially useful to those policymakers and groups that have made significant investments in maize research and development in Africa over the past 20 years. A companion main report more thoroughly chronicles development trends in maize in Africa. This study examines what would have happened to food supplies if this development assistance had not been available. It also provides detailed information at the national level for five countries: Kenya, Malawi, Nigeria, Senegal, and Zaire. In addition to the findings on impact, the study found that many impacts resulting from the use of new technology are hidden, especially in the area of labor shifts—made possible by increased productivity.

In this *Summary Report*, concise tables present the key findings of the project's five individual country case studies. These case studies have also been synthesized in the main report. In addition, full copies of the country case studies—including the *Maize Research Impact In Africa: The Obscured Revolution, Complete Report*—are available on request from the Africa Bureau's Office of Sustainable Development, Productive Sector Growth and Environment Division (AFR/SD/PSGE).*

Completion of this study has involved many individuals and groups. I especially acknowledge the important role of Elon Gilbert, the study's team leader, as well as the other team members. The U.S. Department of Agriculture, Office of International Cooperation and Development, played a key role in assembling the study team and supporting this study. I also acknowledge the important contribution and guidance provided by various USAID technical officers in the course of this research, including Lance Jepson, Thomas Hobgood, Michael Fuchs-Carsch, and Dwight Smith. Finally, I extend a special thanks to the many USAID Missions and National Agricultural Research System leaders in Africa that participated in and supported this study.

David M. Songer
TDT Unit Leader
USAID/AFR/SD/PSGE

* Formerly the Office of Analysis, Research, and Technical Support / Division of Food, Agriculture, and Resources Analysis (AFR/ARTS/FARA).

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The MARIA study research team expresses its appreciation to the Africa Bureau of USAID and its country Missions in which field work was carried out for the uniformly excellent cooperation throughout the conduct of the study. The authors have sole responsibility for the views expressed in the study reports, which are not necessarily shared by USDA, Africa Bureau, or the Missions.

Executive Summary

The Maize Research Impact in Africa (MARIA) study examines the changes on African economies produced by innovations for maize since the 1960s. The study forms part of an effort by the Africa Bureau of the U.S. Agency for International Development (USAID) to assess returns to the investments in agricultural research made by African governments and donors over the past three decades. The choice of maize reflects the attention given to the commodity by research services (national and international), development projects, and policy reforms, as well as its importance in staple food economies of the region. Most significantly, maize was selected because measurable progress has been made across a broad spectrum of ecologies, farming systems, and political-economic conditions.

By conventional measures, maize is a success story. Production in sub-Saharan Africa (SSA) has grown on average by 2.6 percent annually over the past 25 years and outpaced all other coarse grains and agricultural gross domestic product (AGDP) by significant margins. Comparing actual production levels to "without research" scenarios where maize yields either stagnated or declined, SSA data suggest levels of impacts that are at least moderately impressive. The diversity of conditions, however, has affected the magnitude and character of these impacts. Five individual country case studies—Kenya, Malawi, Nigeria, Senegal, and Zaire—explore both the changes associated with the adoption of innovations by farmers in different regions of Africa and the differences in impacts at the national, district, and farm family levels.

The evidence strongly supports the proposition that research contributed to increased returns to both labor and land and thus to the competitive position of maize in relation to other enterprises. Changes in production and productivity must be viewed in the context of resource allocation decisions by millions of farm families who vary widely in their resource endowments. Innovations in maize production and postharvest practices form part of a broad process of adjustment to adversity and response to opportunity that is fundamentally altering agricultural sectors in the SSA region. The response to innovation is related to the position of maize as a food and cash crop in farming systems. Where maize is already the dominant staple, as in Kenya and Malawi, low-resource farmers are apt to use innovations to save resources for allocation to other activities.

Research carried out at the national level has played a major role in improvements in maize production and productivity. Maize research program performance is a function of adequate resources and quality management, as well as the quality and continuity of research staff. Favorable conditions or "windows of creativity," however, have occurred only episodically and were sustained more by the force of personalities than by money, infrastructure, or institutional logic. MARIA suggests that the process of strengthening National Agricultural Research Systems should include special attention to improving the performances of individual researchers under adverse conditions. Towards this end, ways must be found to open more windows for the best of Africa's researchers to be creative in order to accelerate the flow of innovations required for development.

Glossary of Acronyms and Abbreviations

AFR	Bureau for Africa (USAID)
AGDP	agricultural gross domestic product
ARTS/FARA	Office of Analysis, Research, and Technical Support / Division of Food, Agricultural, and Resources Analysis (USAID/AFR, now SD/PSGE)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
CRSP	collaborative research support program
ERS	Economic Research Service (USDA)
FSR	farming-systems research
IARC	international agricultural research center
IITA	International Institute for Tropical Agriculture
MARIA	Maize Research Impact in Africa Project (USAID)
NARS	national agricultural research system
OICD	Office of International Cooperation and Development (USDA)
R&D	research and development
SD/PSGE	Office of Sustainable Development / Productive Sector Growth and Environment Division (USAID/AFR, formerly ARTS/FARA)
SPAAR	Special Program for African Agricultural Research
SSA	sub-Saharan Africa
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture

Introduction

The Maize Research Impact in Africa (MARIA) study examines the changes in African economies produced by innovations for maize since the 1960s. The study forms part of an effort by the Africa Bureau of the U.S. Agency for International Development (USAID) to assess returns to the investments in agricultural research made by African governments and donors over the past three decades. The choice of maize reflects the attention given to the commodity by research services (national and international), development projects, and policy reforms as well as its importance in staple food economies of the region. Most significantly, maize was selected because measurable progress has been made across a broad spectrum of ecologies, farming systems, and political-economic conditions.

Study Scope and Approach

Commencing in January 1991, the MARIA study was carried out over an 18-month period by a group of researchers located principally in Africa. Senegal, Nigeria, Zaire, Kenya, and Malawi were selected as the country case studies. Information collection was extended to a further three countries—The Gambia, Congo, and Ethiopia—although formal reports on these countries are not included in the MARIA study.

The five case study countries collectively contain 39 percent of the population of the region and 28 percent of total maize production. These countries were selected because research and development efforts for maize have produced measurable changes that are indicative of subregional and regional impacts. They are not "representative" of sub-Saharan Africa (SSA), although they do cover a broad spectrum of African geography, ecology, farming systems, and the sociopolitical contexts in which research and development efforts were undertaken.

The study draws extensively on existing studies and secondary sources but also utilizes insights from "key informants," including researchers who participated in maize improvement efforts and the farmers in the regions they served. The study is a collaborative effort involving principal researchers resident in Africa and colleagues who were involved with the case studies for individual countries. For each case study country, consultations were held with representatives of the USAID Mission and the national agricultural research system (NARS) to ascertain their specific interests and questions so that these could be addressed through the case studies as time and resources permitted.

1. A Success Story

By conventional measures, maize is a success story. Production in sub-Saharan Africa has grown on average by 2.6 percent annually over the past 25 years. The increase is traceable to both improvements in yield and expansion in area. While this is not equivalent to population growth, the growth of maize production has outpaced all other coarse grains and agricultural gross domestic product (AGDP) by significant margins.

Two Scenarios

The most obvious impact of maize research is the change in the amount of grain that is produced. MARIA attempts to measure that part of production change that can be traced to research through comparing actual production with different scenarios expressing what might have existed without maize research (Figure 1). The key variables used in the "without research" scenarios are yields and the area devoted to maize cultivation. The scenarios take account of shifts in area to maize from other coarse grains, notably sorghum and millet.

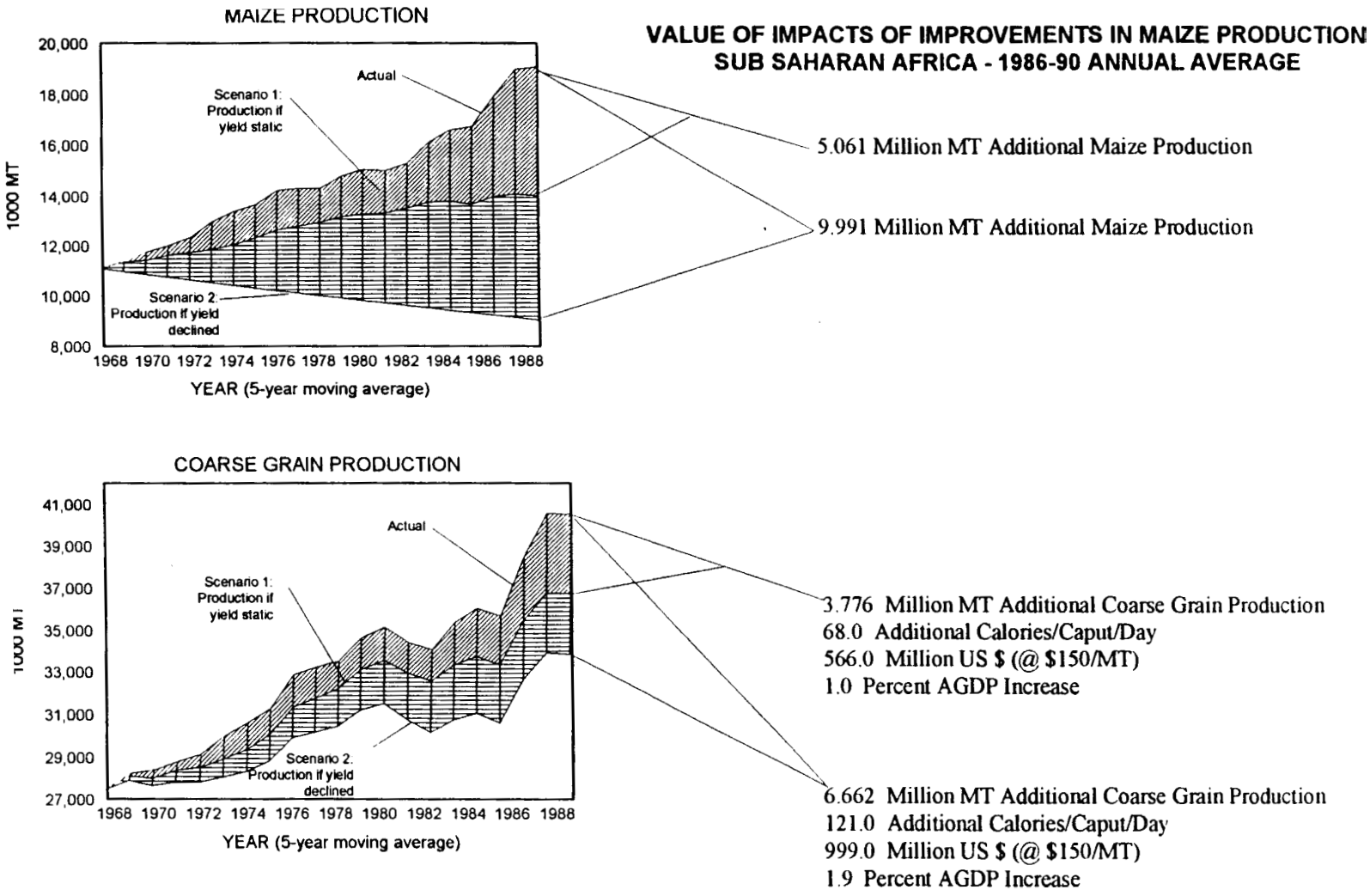
Scenario I (*static yield*) assumes that, without maize research, the yield of maize would have remained at its 1966–70 five-year average level. In this scenario, the area devoted to maize cultivation is allowed to expand as a constant proportion of the area actually put to coarse grains, including maize, sorghum, and millet. For example, if maize accounted for half the total area planted to maize, sorghum, and millet during 1966–70, then it is assumed that the area planted to maize would continue to account for 50 percent of coarse grain area through to 1990. If technologies were absent, resource productivity and the attractiveness of maize production vis-à-vis other coarse grains would have remained unchanged.

Scenario II (*declining yields*) takes account of the effects of pests, diseases, and declining soil fertility. Research has been responsible for incorporating tolerance to selected pests and diseases into improved germplasm as well as providing a range of approaches for maintaining soil fertility. This scenario assumes that average yields would have fallen by 1 percent each year in the absence of these innovations. Sorghum and millet account for all expansion in coarse grain area. In essence, Scenario II postulates that maize would progressively lose its competitive position compared to other coarse grains as a consequence of declining yields.

These scenarios represent two points in a range. While Scenario II is arguably on the pessimistic side, there is no basis to assume that declining yield is a less plausible assumption than simply no change in the absence of research-led innovation. Improvements in production brought about by farmer innovation also lie within this range.

With these scenarios, it is possible to estimate the impact of maize research as the increment in maize production that has occurred over and above the level that would have been achieved without improved technology. For Scenario I, the increment is illustrated by the bold hatched portions of Figure 1. Scenario II produces a larger gap, as indicated by the entire hatched portions of Figure 1. The resulting additional production or gaps can be expressed in terms of calories per capita per day, reductions in imports, and increases in AGDP. From 1986 to 1990, these translate into average annual improvements in maize production of between 5.1 and 10.0 million metric tons and

Figure 1. Sub-Saharan Africa Maize and Total Coarse Grain Production with and without Technological Change



additional coarse grain production of between 3.8 and 6.7 million metric tons. These production increases equate to annual reductions of between US$0.6 and 1.0 billion in imports and increases in AGDP of between 1 and 2 percent.

Using these scenarios, SSA regional data suggest levels of impacts that are at least moderately impressive. However, the diversity of the subregions of West, Central, East, and Southern Africa has affected the magnitude and character of these impacts in any given location. In both relative and absolute terms, data show that maize technologies have had the largest impact on production in East Africa, where maize is the primary staple food. By contrast, impacts on maize production in West and Central Africa are not immediately obvious and are associated with changes in climate, input supply, markets, and farming practices.

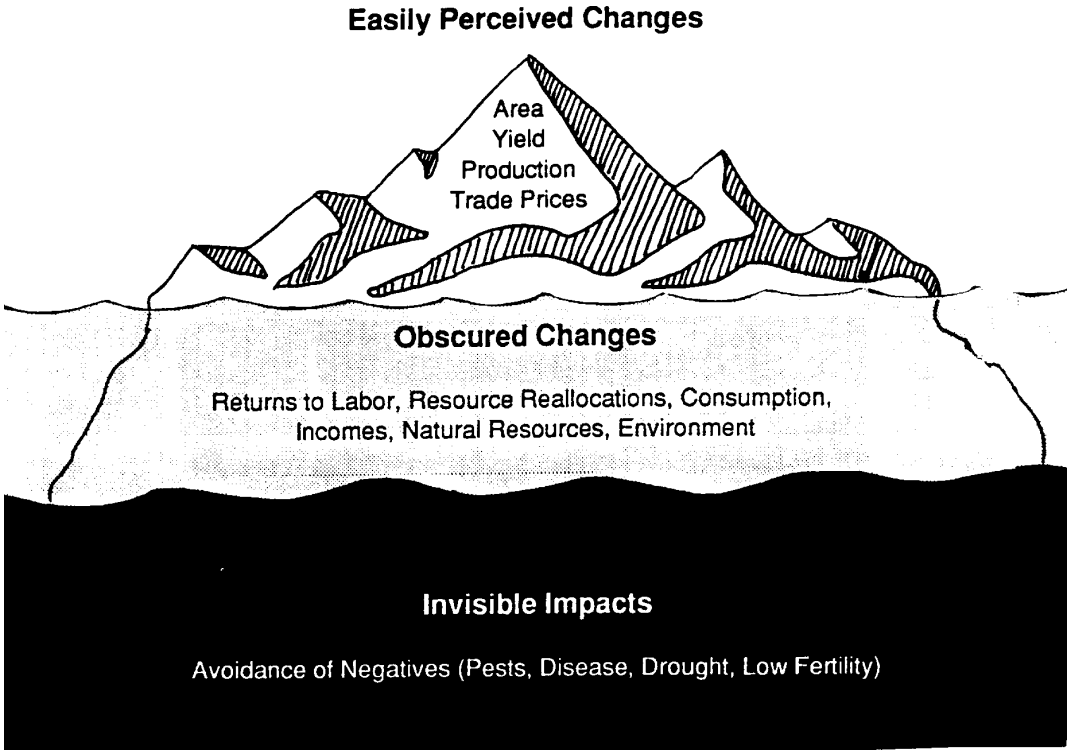
The purpose of the individual country case studies is to explore both the changes associated with the adoption of innovations by farmers in different regions of Africa, and the differences in impacts at the national, district, and farm family levels.

The Impact Iceberg

The impacts estimated through "with and without" innovations comparisons are only one aspect of a complex process of transformation. The true character and dimensions of this change are eclipsed by crosscurrents of policy, environmental changes, war, peace, and structural adjustment. These have ebbed and flowed across the region during the past three decades and have obscured transformation, much as water conceals the larger part of an iceberg.

The changes in production and productivity that have occurred must be viewed in the contexts of resource allocation decisions by millions of farm families. These farmers vary

Figure 2. The Impact Iceberg



widely in their resource endowments and, thus, in the type and scale of benefits derived from adoption and utilization of new maize technologies. Innovations in maize production and postharvest practices form part of a broad process of adjustment to adversity and response to opportunity that is fundamentally altering agricultural sectors in the SSA region. These innovations have increased productivity levels relative to what they otherwise would have been. Improvements in yields usually, but not universally, indicate increases in productivity. For the majority of SSA farm families, however, the productivity of their labor and the stability of their food production are primary concerns.

Technological innovations—including, but not limited to, improved germplasm—have played major roles in the changes that have occurred. These innovations have set in motion sequences of events beginning with adjustments in resource allocations by farm families. The sequences vary markedly from country to country, between regions within the same country, and among different farmers in the same village. It is guided by policies, research and development activities (projects), weather, and, most importantly, the nature of farming systems that reflect the perceptions and aspirations of farm families. Conventional measurements of impact including area, yields, and production can produce deceptive and contradictory results, quite aside from deficiencies in the statistics themselves.

Technological change has been superimposed on an ongoing process of structural transformation and migration that has obscured its impact. Not infrequently, the track of events or impacts leads away from the village entirely and "disappears" into another part of the economy, notably the rapidly growing informal sectors in urban and periurban areas.

2. Five Countries

The five case study countries comprise a variety of sub-Saharan agroecological conditions and socioeconomic contexts that have strongly influenced the character and magnitudes of impacts from improved maize technologies. In spite of these differences, positive changes in productivity associated with innovations for maize have taken place in all these countries. The basic elements of each country's case study are presented in the boxes that follow.

The findings of the case studies were obtained despite the fact that, frequently, data are lacking, particularly in formats that lend themselves to systematically tracking the consequences of adoption for productivity, resource allocations, and consumption patterns. Further, it is difficult to clearly delineate the contribution of research vis-à-vis other factors (for example, extension policy, the political and macroeconomic context, climate, and the farming systems themselves). Despite these difficulties, the case studies do provide evidence of the impacts of technology adoption and the role of research. The sections that follow build on the findings of the case studies and highlight the major lessons with special attention to the role of research.

Maize in East and Central Africa: The Dominant Style

KENYA	**IMPROVED, ADAPTED GERMPLASM; R&D COMMITMENT AND CONTINUITY; SEEDS; SETTLERS**	
Study foci	Machakos District	Western Kenya
Innovations	Early maturing composites	High-yielding varieties; management practices
Role of maize	Primary substance crop	Dominant staple; important cash crop
Key factors	Drought; land available	High potential; dense population; commercial maize producers; good availability of inputs, especially seed
Impacts	More maize production; expansion of farming on marginal land; increased food production capacity	Increased production, through higher yields; capitalized food and seed production by smallholders
	National food self-sufficiency	
Policy context	Consistent government support for agriculture and maize R&D; external assistance nationally orchestrated; R&E linkages have weakened.	
	Less R&D attention	More R&D attention
Equity	Initially, larger commercial farmers in high-potential areas were the beneficiaries. Subsequently, spread to small-scale farmers in other zones.	

MALAWI	**HIGH-YIELDING GERMPLASM; CONSUMER PREFERENCE; SLOW ADOPTION; LAND PRESSURE**
Study focus	Blantyre, Lilongwe, and Mzuzu agricultural development divisions
Innovation	High-yielding dent and (later) semiflint hybrids and composites.
Role of maize	Dominant staple grown on 75 percent area.
Key factors	Consumer preference for local flinty varieties; good but somewhat discontinuous research; uneven input supply; extension through credit clubs; soil fertility decline; land pressure
Impacts	Modest to date, but considerable promise for medium term; returns to labor doubled with hybrid maize; total productivity increased by half. Slow adoption; hybrids grown for sale; increased production and more food available to consumers; maintenance of self-sufficiency.
Policy context	Reasonably consistent support of maize R&D; government monopolies on inputs and output markets.
Equity	Promotion focus on credit clubs, which exclude most low-resource farmers, women.

Maize in West and Central Africa: A Co-Dominant or Secondary Commodity

NIGERIA	**HIGH-YIELDING, DISEASE-TOLERANT GERMPLASM; DROUGHT; R&D MARKETS**
Study focus	Northern Guinea savannah
Innovation	High-yielding composite
Role of maize	Important staple in south; initially minor in north, now an important cash crop
Key factors	R&D collaboration involving national projects/institutions and International Institute for Tropical Agriculture; favorable agroecological environment; southern markets; irregularities in input supply; oil boom and bust
Impacts	Increased yields; expansion in area; shift of resources from millet, sorghum, groundnuts, and cotton; 67 percent increase in national maize production
Policy context	Currency overvaluation; structural adjustment; federal and state government involvement
Equity	No change to existing rural wealth differentials; increased supply for consumers in south

SENEGAL	**ADAPTIVE RESEARCH AND PROMOTION; SUBSIDIZED INPUTS; DROUGHT; TRACTION**
Study focus	Southern Senegal
Innovation	High-yielding germplasm
Role of maize	Food and cash source in early harvest period; secondary food crop on higher-quality land
Key factors	Subsidized inputs; promotion projects; drought; higher returns than groundnuts and other coarse grains on better land; suitable for the use of animal traction
Impacts	Improved productivity of land, labor, resources shifted from sorghum, millet, and groundnuts; doubling in area; tripling in production; foreign exchange saved; local food availability improved in early harvest period
Policy context	Adverse impact of cheap food imports; little government attention; low priority in R&D outside episodic special projects
Equity	Wealthier farmers have easier access to inputs

ZAIRE	**HIGH-YIELDING COMPOSITES; ROADS; MARKETS; R&D PROJECT; DEFORESTATION**
Study focus	North Shaba Province
Innovation	High-yielding composite; management practices
Role of maize	Cash crop; co-dominant staple with cassava
Key factors	Improved access to large, urban markets (roads); strong demand; R&D projects focused
Impacts	Improved yields and labor productivity; 300 percent growth in local production; more resources (land and labor) in agriculture; food imports reduced; expansion of trading; forest land cleared.
Policy context	Little attention to maize R&D; external organizations have been critical to progress.
Equity	Village elite, male farmers were primary beneficiaries; increased pygmy income through labor and farming.

3. Impacts

Virtually all the case studies, as well as other countries in the region, present substantial evidence that innovations produced by research have resulted in significant improvements in maize production and factor productivity in sub-Saharan Africa. These improvements have been associated with a major expansion in maize production since the 1960s, averaging 2.6 percent annually for the SSA region.

Increased Productivity

Innovations for maize have increased the productivity of land and labor across a broad range of farming systems.

Sources of Growth

The statistical indicators at national and regional levels show improvements in yields; on average, these have grown by 0.7 percent annually throughout SSA. The impacts of innovation on land productivity are partially obscured by expansion into marginal zones, higher intensity of cultivation over time, and decline in fertility. Higher crop yields, however, are not a major reason why many farmers adopt innovations. The evidence strongly supports the proposition that research contributed to increases in returns to labor and land, and thus to the competitive position of maize in relation to other enterprises.

Area expansion has been an important component of maize production increases in all case study countries. For the entire SSA region, area increases were the source for roughly two-thirds of the 2.6 percent average annual growth rate of production since the late 1960s.

Consistent with expectations, most of the expansion of maize area appears to have been at the expense of other agricultural enterprises, rather than through movement onto new lands. These shifts were stimulated by innovations and are discussed below. The major exception among the case studies is Zaire, where area expansion involved accelerated clearing of forest land.

All the case studies provide at least qualified support for the notion that the character and magnitude of impact is related to the initial position of maize in the farming systems and diets. The maize-dominant systems of East Africa have accounted for the largest aggregate impact—over half the growth in sub-Saharan output, while systems in Central Africa, where maize is a secondary crop, have made the smallest contribution. Nevertheless, the relationship between the role of maize and the magnitude of production increases is not as close as expected. The case study countries have illustrated important qualifications.

Possible contradiction is found within Nigeria. The major expansion of maize in Nigeria has occurred in the north, an area where maize was previously an insignificant crop. In contrast, improvements in maize production have been much slower in the south, where maize continues to be a secondary staple and regularly traded in urban markets. The experience of Nigeria illustrates the advances that can be achieved when appropriate technology and favorable ecological conditions (the northern guinea savannah zone) are linked with strong demand and adequate market infrastructure.

The progress in Malawi compared to that of Kenya demonstrates the potency of demand for research. Maize is more important in Malawi

Table 1. Average Annual Growth Rate, Maize Area, Yield, and Production, 1966–88* (by region)

Region	Area %	Yield %	Production %
East	1.76	1.98	3.78
Southern	0.96	0.04	1.01
Central	2.84	0.12	2.97
West	2.40	0.49	2.90
Total SSA	**1.80**	**0.74**	**2.57**

*Five-year moving average.

Source: USDA/ERS.

Table 2. Average Annual Growth Rate, Maize Area, Yield, and Production, 1966–88* (by country)

Country	Area %	Yield %	Production %
Kenya	1.87	1.14	3.03
Malawi	1.04	– 0.17	0.87
Zaire	2.17	2.15	4.36
Nigeria	2.56	0.00	2.56
Senegal	3.47	2.08	5.62

*Five-year moving average.

Source: USDA/ERS.

than Kenya, although both countries have maize-dominant food economies. Yet production increases to date have been greater in Kenya than in Malawi. The difference is partially explained by the early impetus given to Kenyan maize R&D by settlers in the 1950s. The research associated with current advances in maize in Malawi started two decades later, and the spread of improved germplasm is still very much in progress. The effective demand for research results and high-quality seed from commercial maize production sectors in Kenya and Zimbabwe clearly influenced the timing and levels of effort for maize research as well as its character.

Resource Allocations and Consumption Patterns

In each of the case studies an effort was made to understand farm-level decisions from the perspective of productivity changes. Economic logic implies that, to either increase productivity or at least reduce the risks of losses from negatives such as drought and disease, farm families will adopt innovations as opposed to

simply expanding area devoted to a particular commodity. Large numbers of maize farmers have realized significantly higher returns from improved seed and fertilizer introduced as a result of research.

Other factors, including policies, input supplies, political conditions, and the nature of the farming systems involved, have clearly influenced the magnitude, scope, and timing of the expansion of maize production, but innovations, particularly improved germplasm, are specifically associated with improvements in productivity. These improvements translate directly into more resources through increasing output of maize and freeing land and labor for other activities. An intriguing dimension of the MARIA study is the better appreciation of what farm families in different circumstances actually do as a consequence of increases in productivity. This set of responses, which frequently seem to offset one another in higher levels of statistical aggregation, define impact.

Perhaps the single most important lesson of the MARIA study relates to the limitations of conventional approaches to assess the impacts of research. Measures of impact that focus exclusively on changes in area and yield of maize are likely to miss significant portions of the contribution made by innovations. Such measures are the visible tip of the impact "iceberg," much of which is not easily discernible through national statistics. This is particularly true for innovations that primarily improve returns to labor as opposed to land, such as mechanization, or reduce negatives such as the use of disease tolerant varieties and techniques to offset the effects of drought and fertility decline.

The Impacts Iceberg

A significant portion of impacts are associated with improvements in returns to labor, reduction of negatives, and reallocation of resources that are not readily visible through available statistics.

Competitive Position of Maize

Innovations have improved the competitive position of maize vis-à-vis other agricultural enterprises.

Technology has improved maize's competitive position compared to other commodities in all the case study countries. Conventional wisdom suggests that improvements in factor productivity associated with a particular commodity (for example, improved seed) will attract additional resources, notably land and labor, as well as the funds to purchase the innovation, into the production of the commodity. Maize area has expanded in all the MARIA case study countries. However, there is some question as to the degree to which the expansion was influenced by innovations in Zaire and Malawi. Thus, if impacts are measured solely through changes in maize production, areas and yields can overstate the net effects of research as well as ignore other aspects of technology adoption.

In Malawi, there is limited scope for expansion since land is limited and maize already accounts for a high percentage of area cultivated. In Kenya, new varieties are associated with the expansion of maize production at the expense of grazing in marginal areas such as Machakos District, but elsewhere, especially in the higher potential areas, increased maize yields enabled farmers to shift resources to more profitable crops (for example, coffee, tea, and horticultural crops) while still meeting their food production objectives.

Evidence from Senegal and Nigeria strongly suggests that farmers expanded maize area in response to its convenience and relative profitability compared to sorghum, millets, and groundnuts. The yield differential was already there, but efforts to promote new varieties gave considerable momentum to the changes that took place. Maize is also attractive in these countries because of its early-maturing characteristics and its contribution to food supplies

Resource Reallocations

The effect of innovation on household resource allocations is a function of the position of maize and where a family stands in relation to its food production objective, in addition to perceptions of returns to alternate activities. In maize-dominant systems, farmers may use innovations for maize to "save" resources for reallocation to other enterprises.

during the early harvest period when food is normally in short supply.

In Zaire, the increased profitability of maize production has provided farmers with resources, especially income, to diversify into nonfarm activities such as trade. In Senegal and Nigeria, increased income has been partially directed toward investments in farm capital such as animals and traction equipment and increased use of inputs such as fertilizer.

Where maize is a dominant staple crop as in Malawi and Kenya, responses at the individual farm level can be quite different. Response depends on the importance that families place on meeting their own food needs and on where their current mix of farm enterprises places them in relation to that objective. Families that are already self-sufficient or become so as a consequence of adopting the new technology may opt to shift resources out of maize, despite the improved competitive position of maize. Whether they do or not depends on the returns to maize production vis-à-vis the range of alternate uses of available resources. Clearly, some farmers may find it is in their interests to produce maize for market and will expand production accordingly. However, in maize-dominant systems, the response to innovation might take the form of a combination of higher yields, stagnating or declining area, and increases in the production of maize that are roughly equivalent to population growth.

The relationship between production for home consumption objectives and technology adoption and subsequent adjustments in resource allocations is not well understood and can lead to erroneous conclusions on the nature of impacts. The perspective that many farmers adopt innovations primarily to "save resources" devoted to a commodity may or may not be implicit in the themes and criteria utilized by researchers, but the results of the MARIA study strongly suggest that it should be.

The case studies suggest three qualifications to the preceding discussion. First, a growing number of farm families in SSA depend on the market for meeting a portion of their basic staple food needs. In some instances, as in Malawi, they have little choice given the shortage of land. In Senegal and The Gambia, coarse grain production has expanded at the expense of groundnuts, the traditionally dominant cash crop, in response to drought and unattractive producer prices, but the majority of producers in both countries remain heavily dependent on the market to meet a significant portion of their basic food needs. In essence, the distinction between cash and food crops is becoming less relevant, and technological change for food crops, especially ones that improve the stability of production, can be viewed as a means to accelerate this process.

Second, many consumers are diversifying their diets subject to their ability to do so. The dominance of traditional staples is often more a function of poverty than food preferences. In recent years, maize has become increasingly important in the diets of Nigerians, Senegalese, and Ethiopians, reflecting a willingness of consumers to make changes, especially if they can

Dependence on Markets

Many farm families consciously opt to produce food below their capacity to do so and depend on markets for a portion of their basic food needs to allocate resources to other activities.

Diversification of Diets

The expansion of maize in areas where it was not traditionally important reflects a willingness to diversify diets, especially where expenditures of food and/or resources devoted to food production can be reduced in the process.

reduce their expenditures on food.

This dietary diversification should work in favor of maize in parts of the region which are suitable to its production but where the commodity is still relatively unimportant. On the other hand, poverty, drought, and advances in technologies for other coarse grains may favor the expansion of commodities such as sorghum and millet at the expense of maize in portions of East and Southern Africa.

Third, improved hybrids and other varieties may differ significantly from local types. In Malawi, local flinty varieties are grown to meet household food needs while hybrids are produced for sale. The hybrids have the added benefit of being a reasonable, but less-than-perfect substitute for local maize as food. The difference between improved and local varieties becomes less important as food preferences and the characteristics of improved cultivars converge. In Kenya and Zimbabwe there was little difference which greatly speeded adoption, while in Malawi the divergence constrained adoption. This distinction is less of a factor where farmers expand production primarily as a source of cash as in Zaire and northern Nigeria.

New Varieties or Commodities?

Characteristics of new varieties may differ so much from locals that farmers regard them as different commodities. Hence, the decision in some countries (e.g., Malawi) to produce local maize for food and improved varieties for sale.

Equity and the Environment

Maize expansion, like all extension of cropping areas in Africa, has negative environmental consequences. Croplands are eroding dry-season pastures and woodlands in arid areas and invading the rain forest. The root cause is not maize or innovation, but population pressure. Where improved maize has increased the productivity of cropped land, it has partially offset growing stress on the environment. In Zaire, however, the profitability of maize production in medium and high-altitude rain forests has meant that farmers clear land specifically to plant maize. The challenge to researchers, government decision makers, and local communities is to define the combination of policies and technologies that can bring about a greater convergence of individual and societal benefits in approaches to land use.

Equity

Larger producers have benefited more proportionately from maize innovations than small, low-resource farmers. However, medium to small farmers increasingly dominate maize production and in aggregate have benefited more.

Socioeconomic equity has been enhanced by agricultural research generally and maize technology in particular. Where prices have not fallen too far, cash-cropping of maize sold on the domestic market has helped redress urban-rural imbalances. Within rural communities, large commercial farmers, particularly in Kenya and Zimbabwe, were the first to profit from the advances in maize technology, and in terms of gains per farmer, per hectare, or even per unit output, they have benefited proportionately more than small-scale farmers. However, smallholders have more than caught up despite the high resource and management bias of the technologies. The share of small-scale produc-

tion appears to have gained in relative importance throughout the region as shifts in pricing policies during the last decade led to the rationalization of commercial maize production. In aggregate lower-income groups, producers and consumers have probably benefited more despite smaller individual gains.

In West and Central Africa, large commercial farms are less important, although maize technologies may have contributed to income disparities between rich and poor producers at village level. Nonetheless, green maize has an increasingly important role in meeting the food and cash needs of poor households during the early harvest period. Both rural and urban consumers have benefited from greater supplies and lower prices of maize.

There is no evidence that increased productivity has diminished the access of women or other disadvantaged groups to resources. Overall, women have benefited from improved productivity and, where maize has replaced sorghum or millet, they have benefited from the easier processing characteristics of maize. There is no indication that consumers, or laborers paid in kind, have suffered from changes in the nutritional value of improved maize varieties. However, disadvantaged groups continue to be discriminated against in access to inputs and credit associated with efforts to promote innovations, especially in Malawi.

4. The Roles of Research and Technology Transfer

The country case studies leave little question that research, particularly research carried out at the national level, has played a major role in improvements in maize production and productivity. Considerable quality research has taken place and usable results have found their way out to large numbers of farmers.

The quantity and quality of attention given to maize by research institutions varies significantly among the case study countries and over time. At one end of the spectrum is Kenya, where maize is a long-standing priority concern. The Maize Research Program has been responsible for producing a series of innovations that underlie the progress in Kenyan maize production. Maize in Malawi has also received considerable attention for over a decade. The continuity of staffing and support that the maize research team has received is beginning to translate into major benefits for maize producers and the country as a whole. At the other end of the spectrum, maize received only modest attention by the research establishments in Senegal and The Gambia. Progress was made in part because adaptive research was an integral part of development projects.

Research Management and Performance

Maize research program performance is a function of adequate resources and quality management, as well as the quality and continuity of research staff.

Zaire and Nigeria fall between the two extremes. Nigeria has a large national program and the roles of national institutions were important in the initial transfer activities in the 1970s. The activities of international agricultural research centers (IARCs)—namely, the International Institute for Tropical Agriculture (IITA) and Centro International de Mejoramiento de Maiz y Trigo (CIMMYT)—have been a positive factor, compensating in part for the uneven resources available to national programs. As the host country, Nigeria has received a major share of IITA's attention for maize. In Zaire, it has been difficult to sustain any national maize effort outside the AID-supported projects which were implemented initially under CIMMYT and subsequently by IITA. The weakness in the national program has seriously limited the effectiveness of maize research, especially during the 1980s.

The implementation of agricultural research on maize in several countries has been less efficient than can be readily justified by the requirements of institutional development and the inevitable false trails of the scientific discovery process. Most of this inefficiency is associated with situations where research was simplistic in conception (or just wrong), erratically sustained, weakly linked to clients (or heavily weighted toward commercial farmers in high-potential areas), and confounded by perverse policies and institutional jealousies. Progress was often much slower than it needed to be. Releases of new technologies and adjust-

Windows of Creativity

A significant portion of the progress in maize research is traceable to certain periods or "windows" in which individuals combined with conditions that fostered creativity and performance.

External Institutions and Support

External institutions and support have been associated with much of the progress in maize R&D in the region.

ments in recommendations were hampered by inertia and excessive caution.

The record of maize R&D in SSA consists of a number of bright spots and many missed opportunities. In nearly all the case study countries, major progress in maize R&D is traceable to specific individuals and time frames. These "windows of creativity" were brought into being and sustained for periods of time more by the force of personalities than by money, infrastructure, and institutional logic. The latter are certainly required and can be replicated in successive research projects, but scientific leadership and the conditions that foster creativity and performance involve much more than training, technical assistance, capital equipment and operating funds.

Research institutions including those that comprise the national agricultural research systems (NARSs) and the range of external agencies—for example, IARCs, collaborative research support programs (CRSPs), regional organizations, and institutions in developed countries—have been the recipients of considerable support from national governments and donors. On balance, outside involvement has been positive and productive. In Kenya and Malawi, donor support and external linkages were "orchestrated" by national programs, although, more often than not, it has been the other way around in African countries. To a great extent, the set of impact assessments of which the MARIA study forms a part, is a reflection of doubts about the utility of such support, particularly the feasibility of developing sustainable research capacities at the national level in most countries of the region.

Integration and Linkages

The functional integration of adaptive research, promotion, and input delivery within the same organization has been more effective than efforts dependent on the coordination of different actors through linkage arrangements.

In all case study countries, there have been periods of concerted effort to identify, adapt, and transfer technologies for maize. Effective linkages between research and extension, sometimes in the form of functional integration within the same project, are critically important in understanding progress in production and productivity in Senegal, Nigeria, and Zaire. The linkages were also strong in Kenya, particularly during the 1960s and 1970s. Linkages have been least impressive in Malawi, which partially explains the slow rate of adoption of improved germplasm.

Considerable progress has been made in the area of research-client linkages during the 1980s, partly as a consequence of farming-systems research (FSR)–type activities supported by IARCs, USAID, and other donors in the region. More attention is now given to the needs and constraints of specific farming systems in defining research themes and assessment criteria than was true in the 1970s. In addition, technology transfer to extension services is receiving greater emphasis, both directly as components in R&D projects and indirectly through an upsurge of concern about impacts.

Redundancy is frequently regarded as something that should be avoided. Numerous reports site functional overlaps and call for stricter divisions of labor. Yet the experiences of sev-

Redundancy

Redundancy in services, particularly under adverse conditions, has been critically important in achieving progress in such areas as input supply and promotional activities.

eral countries, especially Zaire, strongly suggest that a degree of redundancy has been critical in maintaining momentum of development efforts and achieving impacts. This appears particularly true where conditions for development are generally poor. Although redundancy can be wasteful, it can also help ensure that progress takes place under adverse circumstances.

Efforts to strictly define maize R&D responsibilities along institutional lines may be misguided, especially when a number of different organizations are involved. Where institutions function poorly, they are less able to link and coordinate activities efficiently. Integration of R&D responsibilities works best in such situations, even if this involves functional overlaps among organizations.

Input availability emerges as a particularly important factor explaining the rate of adoption of innovations. Although inputs were often supplied by special projects to compliment the promotional work, arrangements and availability frequently became erratic and unreliable, especially as the projects came to an end. In Zaire, the existence of functional overlaps between agencies helped ensure that inputs got delivered.

Despite variation in the quality of maize research management in the case study countries, to some extent they all enjoyed policy environments that favored maize research and development at least for specific periods of time. In the maize-dominant systems of East and Southern Africa, this support has been institutionalized. However, pricing and marketing policies in Zambia, Zimbabwe, and Kenya have worked both for and against producers in an effort to keep cheap food available for urban consumers. Prices and markets have enjoyed a lack of regulation in most of the countries of West and Central Africa, partly because maize is not an important food source in these parts of the region. Nonetheless, subsidized and readily available inputs have been prominent features of projects promoting maize in Zaire, Senegal, Ghana and Nigeria.

Despite favorable policies and programs for maize, the general contexts in most case study countries were less than positive and constrained R&D activities. Trade regulations, however, have not been a significant factor apart from Nigeria, which banned cereal imports in 1985, and Senegal, where cheap imports of maize competed with local production to supply poultry producers.

5. Conclusions

While our understanding of research needs has improved substantially during the past decade, the capacities of many NARSs remain low or are diminishing. In many instances the performance levels of NARSs have not responded to major institutional development efforts. The conditions that fostered achievement and creativity in maize research in specific countries (for example, Kenya and Zimbabwe) prior to 1980, tend to be the antithesis of those currently found in the public services of most African countries. Structural adjustment policies aimed at controlling the scope and scale of government activities generally thwart the capacities and performance levels of research services, while, in several other countries, civil unrest has brought virtually all research activities to a halt. Frequently, national researchers leave key NARS institutions as fast as they are trained. Numbers seriously understate the impact of attrition on the quality and quantity of research by NARS, since those leaving include a high proportion of the most able.

These conditions have led some donors, including USAID, to question the utility of further support for agricultural research. Reductions in assistance to NARSs have tended to convert negative appraisals into self-fulfilling prophecies. There is a serious danger that the considerable progress already made in developing the next generation of innovations for maize and other commodities will be dissipated in the process—especially at the adaptive end of the research spectrum. While classic forms of the Green Revolution are unlikely in SSA, there is substantial scope for further improvements in productivity through the research now in progress as well as the selective use of innovations already available. This is particularly true in countries that have been insulated from technological change by isolationist and perverse policies (Guinea), civil war (Mozambique, Sudan, Angola, Ethiopia), or neglect (Congo).

Is the glass half full or half empty? Despair is perhaps the easiest conclusion to reach. Yet that conclusion ignores the fact that significant progress has taken place in selected countries and commodities, often in the face of adversity. The qualified success of maize in Africa provides evidence that substantial benefits can and did flow from the investments in agricultural research. What might have happened if conditions had been more favorable? If only some of the negative factors had not been present? Zimbabwe, during the immediate postindependence period (1980–85), is a good illustration of the dramatic results that are possible when there is a strong confluence of favorable factors.

The discussion assumes that expectations for technology include improved incomes and food security, especially for low-resource farm families. A further supposition is that concerns about impact will continue. An important message of the MARIA study is that the nature of change and transformation in SSA agriculture is complex and frequently appears contradictory, particularly when viewed through national statistics. Discrepancies stem in part from the diverse responses of millions of farm families to adversity and opportunity. A commitment to better understand what is happening should resolve these questions and prevent them from continuing to undermine our confidence in Africa's ability to progress. This should not necessitate a major increase in resources available for monitoring, evaluation, impact assessment, and adaptive research, provided there is better synchronization of these activities within

institutions and projects. In addition, there is considerable scope for expanded participation by extension services, nongovernmental organizations, input companies, and farmers themselves, using the range of approaches that have been developed by FSR projects in particular.

How good a guide is the past for the future? Using hindsight, the MARIA study has shown that major efficiencies could have been realized in research investments. As with education and curative medicine, our institutional models for NARSs were probably inappropriate for most of SSA. Yet quality research that resulted in positive impact took place in a variety of conditions and structures. For given periods of time, windows existed that fostered scientific creativity.

There will be a continuing role for NARS in this process, but the nature of that role is likely to differ substantially between countries depending on their policies, priorities, and capacities. Fresh frameworks for structuring sub-Saharan agricultural research are likely to emerge as individual NARSs gain a better understanding of their comparative advantages and the means by which they can enhance both their participation in, and their service from, regional and international institutions and networks. New models must, above all, offer hope. They must change the negative or even cynical perceptions that researchers, national governments, and donors currently have of their NARSs. Otherwise, the plans "will do little more than restructure mismanagement, reallocate frustration, and define problems for which no solutions will be forthcoming."*

What that new framework might look like is well beyond the scope of the MARIA study. The efforts that national governments and donors are now making through the Special Program for African Agricultural Research (SPAAR) and selected regional programs offer considerable promise for the future. The deliberations to date reflect a more realistic assessment of the limitations of NARSs and a willingness to explore new modes of regional collaboration with emphasis placed on enhancing the performance and contribution of African scientists. Institutions, whether they be IARCs, NARSs, or some new form of regional collaboration are a means to this end.

The MARIA study offers two suggestions for the future. First, we should reassess approaches to strengthening NARSs giving special attention to improving their performances in the face of adversity. Conventional approaches routinely seem to require better political and socioeconomic contexts than much of Africa is likely to offer before the end of the century. Rates of research failure can be reduced through efforts to eliminate debilitating interruptions in staffing and resources for high-priority activities. Second, the new frameworks should emphasize human resource management systems that are guided by accountability, stewardship of innovations, performance, and, above all, creativity. Although training should continue, the focus should shift to enhancing the performances of staff at post. National and external research institutions can collectively produce the innovations that will move Africa forward. Towards this end, ways must be found to open more windows for the best of Africa's researchers to be creative in order to accelerate the flow of innovations required for development.

*International Service for National Agricultural Research (ISNAR), *National Agricultural Research Strategy and Plan for Uganda*, vol. 1, chap. 2 (The Hague: ISNAR, 1991).

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