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MSU International Development Working Paper No. 49
1995

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East Lansing, Michigan 48824

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by

Duncan Boughton*, Eric Crawford*, Julie Howard***, James Oehmke**, James Shaffer*, and John Staatz***

March 1995

This paper is published by the Department of Agricultural Economics and the Department of Economics, Michigan State University (MSU). Funding for this research was provided by the Food Security II Cooperative Agreement (AEP-5459-A-00-2041-00) between Michigan State University and the United States Agency for International Development, through the Africa Bureau's Office of Sustainable Development, Productive Sector Growth and Environment Division, Technology Development and Transfer Unit (AFR/SD/PSGE/TDT).

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ISSN 0731-3438

Published by the Department of Agricultural Economics and the Department of Economics, Michigan State University, East Lansing, Michigan 48824-1039, U.S.A.

EXECUTIVE SUMMARY

Recent studies have shown that agricultural research can have high payoffs in Africa, but impact depends on how well technology fits with evolving needs and capacity in the agricultural sector and the rest of the economy. Structural adjustment policies (e.g., market liberalization, currency devaluation) and political change are transforming user demands for new technology and the economic environment in which technology must perform. The challenge is how to design agricultural research as a strategic input to promote broad-based economic growth, structural transformation, and food security in the increasingly market-driven, but fragile, economies of Africa.

Vision, strategy, tactics. A process for designing agricultural research as a strategic input will have three distinctive characteristics: (1) a **vision** that recognizes the link between research and agricultural transformation. The transformation from low-income agricultural economies involves increasing specialization and productivity in farming through the acquisition of science-based inputs from the rest of the economy in exchange for farm products. But this transformation will only occur if the agricultural sector and the broader economy are effective in delivering the required inputs (including food and other consumer goods) to the farming sector, and stimulating labor markets and off-farm enterprises to employ labor not required for farming in more productive activities. This implies the need for (2) a **strategy** that ensures consistency and complementarity between technological change and improvements in institutions and policies necessary to foster greater integration and exchange within the economy, and for (3) **tactics**, the development of feasible action plans, that bring together research clients and stakeholders.

The vision: structural transformation. Historically, every major country that has substantially improved real incomes has done so through a structural transformation of its economy. This transformation results in the generation of increasing proportions of employment and output of the economy by sectors other than farming. The economy becomes less agriculturally oriented in a relative sense, although farming and the food system continue to grow absolutely and generate important growth linkages to the rest of the economy.

Structural transformation also means a movement of the economy away from subsistence-oriented household-level production towards an integrated economy based on greater specialization, exchange and economies of scale. Many functions that used to be conducted on the farm, such as input production and output processing, are carried out off the farm. One implication of this process is that driving down the real cost of food to consumers requires fostering technical and institutional changes in the off-farm elements of the food system, as well as at the farm level. Another implication is that in order for structural transformation to go forward, the economy must develop low-cost means of exchange. High transaction costs in the economy can choke off structural transformation by making it too costly for people to rely on the specialization and exchange necessary to take advantage of the new technologies in the food system.

The role of NARS in agricultural transformation: a framework. We start with the concept of a production-distribution-consumption sequence (PDCS) with two basic units of observation: physical transformations and transactions (Figure 1, p. 9). Physical transformations are the result of combining two or more inputs to make an output. Transformations are linked by transactions. A portion of one PDCS is illustrated in Figure 1. Here, the outputs from fertilizer manufacture, the on-farm production of labor, and animal power and manure from on-farm livestock production are brought together (through transactions) in the production of maize. The maize grain and stalks produced in turn are sold, given or traded as inputs to the subsequent production of maize meal, dairy or meat products, or additional on-farm labor. With each of these separable transformations, specialization is possible. In theory, each transformation can be handled by a separate individual or group of individuals. These different groups are then linked by transactions. An economy can be defined as a system of interrelated PDCS.

Facilitating structural transformation requires increasing the productivity of the food system PDCS. This can be accomplished in two ways: (1) raising the productivity of the individual transformations in the PDCS through technological change, and (2) improving the coordination among the individual physical transformations.

Increasing the productivity of individual physical transformations and improving coordination are, in practice, highly interdependent. For example, in much of the food system, the physical transformations are time-dependent. Fertilizer applied at the wrong time in the growing season may lower rather than raise grain output. Thus, realizing potential productivity gains offered by the development of a new fertilizer-dependent variety requires adequate coordination between input providers and farmers. In short, technological improvements and improved coordination can be thought of as two sides of a coin needed to increase productivity and foster structural transformation.

Operationalizing the vision. In going from a broad mandate to an operational plan, the research organization must first define more precisely the aims of its research program and the assumptions underpinning it. *What weight will be given to different performance dimensions*? For example, it has to be decided if research will focus on increasing the total value of agricultural output, regardless of where it is produced (an efficiency goal). Alternatively, greater weight may be given to increasing the productivity of crops grown by the poor (an income distribution goal). Strategic planning has to take into account the potential tradeoffs among these criteria and others such as the sustainability of natural resources.

Defining the clients and stakeholders for the research organization involves determining whose preferences count in the design of the research program. A client is an intended recipient of specific agency benefits. There has been a tendency to think of farmers as the clients of agricultural research, but improving food security and food system performance requires increased productivity throughout the food system, not just at the farm level. This suggests that if the aim of agricultural research is to boost productivity in the food system, the clients of the research include groups other than farmers, such as merchants, processors, input suppliers, and consumers. Just as the research system has to decide which weights to give to different

performance dimensions, it also has to work out how to weight the interests of different clients and stakeholders.

The effective participation of this expanded set of research clients in the planning process is a key to making the selection of research priorities more market-responsive. Beyond this, client and stakeholder networks constitute a potentially powerful coalition that can support and monitor the implementation of research programs themselves. Just as important, they can identify and facilitate the implementation of institutional and policy innovations critical for adoption of technology.

The objective of strategic planning for NARS is to improve the probability that research resources will be invested where they will have a high payoff. The planning involves making educated guesses about where research will be most productive. But estimates of the payoffs to different lines of research depend critically on *what researchers assume about the political-economic conditions that will prevail in the future*. For example, the question of whether the development of high-yielding, fertilizer-responsive varieties will have a high payoff depends in part on what is assumed about the future availability of fertilizer at the farm level.

Researchers can make at least three different broad sets of assumptions about political-economic conditions. First, they can assume that the current situation will continue unchanged. This approach says that the research program should adapt to current conditions regarding, e.g., the availability of purchased inputs, opportunities in export markets, and the overall policy environment. Second, researchers can assume that political-economic conditions will change in the future, and that it is possible to make predictions about how those conditions will evolve. The research program will then be designed to take advantage of the predicted future conditions. This set of assumptions sees the future as dynamic, but not influenced by the research system itself.

Finally, researchers can assume that the future is both dynamic and that they can influence it. This approach is proactive and assumes that the strategic planning process will identify changes in the political-economic conditions that could increase the payoffs to particular lines of research, and help mobilize support from client groups and policymakers to change those conditions. The strategic planning approach that we present is consistent with this third approach. It sees agricultural researchers influencing how the future political-economic environment facing the food system evolves.

The food system matrix and subsector analysis: tools for analyzing the food system. In order to develop a workable research plan, researchers must come up with a way of describing and analyzing the food system in a manageable way. For example, one can visualize the food and fiber sector as a food systems matrix. The matrix is multi-dimensional, and can be viewed as a series of overlaid 2-dimensional matrices. Figure 2 (p. 18) shows one two-dimensional representation of the matrix, with commodities depicted as columns and various stages in the vertical transformation process depicted as rows. Technology development and transfer can make contributions to all the production and distribution functions shown in the various cells.

Historically, agricultural research has focused primarily on problems that fall into individual cells—e.g., farm-level production constraints for millet. However, both farming systems research and subsector approaches address problems that span the various cells in the matrix and analyze how a coordinated approach to research on problems in different cells can increase the productivity of the technology development and transfer system. For example, research on urban consumption patterns for coarse grains may lead to major insights about the attributes that breeders need to stress in their selection programs. Hence, research and extension need to address both physical transformations (represented by individual cells in the table) and the coordination among those transformations.

The food systems matrix identifies classes of important relationships in the sector viewed as a system. The matrix helps to identify questions and data relevant to evaluating the probable value of alternative programs of research and related programs, by directing attention to important relationships in the system likely to be influenced by the research. The matrix is also useful for identifying barriers to improved performance and unexploited opportunities, thus identifying potential opportunities for high-payoff research and complementary programs.
Subsectors are defined as the sequence of activities contributing to the production, distribution and use of particular commodities. A subsector is depicted as a vertical slice in the food systems matrix. The emphasis in subsector analysis is on descriptive diagnosis of potential opportunities and constraints in the vertical sequences in production and distribution and their coordination. The focus is thus on the coordination between stages, e.g., from the point where a commodity is produced on farms until it loses its identity in meals or in industrial processes. An initial description of the subsector shows the channels and transformations of the commodity; data (when available) indicating volumes and values of the commodities in various forms; and costs, by source, as the commodities pass through the different stages and channels. Most importantly, the analysis focuses on the vertically integrated processes of transformation and coordination throughout the subsector and on identifying problems and opportunities to improve performance.

Strategic planning as a process. Strategic program planning must be a continuing, institutionalized **process** of problem solving and allocation of resources, not a one-shot exercise. The uncertainty inherent in technology development for rapidly changing food systems requires a planning process that is able to adjust priorities and activities in response to new opportunities or changed conditions.

Strategic Agricultural Research Program Planning (SARPP) can be thought of as a sequence of questions whose answers will help to define a vision, strategy and tactics that will lead to a greater payoff to investments in the research program. These include:

- What are the development goals and objectives for the agricultural sector, commodity subsector (or geographical region or resource) that a research organization or program is concerned with?

- What are the major constraints (with regard to technology, infrastructure, institutions and policy) to the realization of those goals and objectives, and what

are the relevant boundaries for analysis of the constraint (regional, national, sub-national)?

- What are the opportunities for technological innovation at the farm and/or other stages in the food system? Do the technologies exist or must they be developed, and if they exist at what level (national, regional, international)?

- To what extent are potential technical innovations dependent on or responsive to investments, or policy or institutional innovation in the food system?

- Who are the relevant direct clients (technology users), indirect clients (those other than technology users who gain or lose from adoption) and stakeholders whose participation is necessary to help define and realize the potential contribution of agricultural research?

- How can the planning group choose among (prioritize) alternative opportunities to match activities to available human and financial resources?

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1. INTRODUCTION

This paper discusses an approach to strategic planning for agricultural research in sub-Saharan Africa. The paper is not a cookbook about how to carry out such planning. Rather, it presents a way of thinking about how agricultural research can be designed as *a strategic input* to promote broad-based economic growth, structural transformation, and food security.

For agricultural research to play this role, strategic planning is needed concerning:

- How agricultural research fits into the broader development process, and how this role can be articulated in agricultural policy.

- The contributions and comparative advantages of various parts of the agricultural research system in fostering agricultural transformation (private sector, including farmers; CG centers; regional centers; NARS; and individual entities within NARS, such as agricultural research institutes).[1]

- The level, types, and mix of activities carried out in agricultural research institutes (staffing levels, commodity focus, mix of applied and adaptive research).

- The design of individual research programs.

The paper places most of its focus on NARS and their component parts, but stresses the importance of:

- distinguishing clearly among these various levels when designing strategic planning activities; and

- coordinating activities at all these levels if work within NARS is to be productive.

The paper follows from two lines of past research. One was research evaluating the economic returns to agricultural research in Africa. The second focused on the problems of economic coordination and the barriers to improved performance of food and agricultural sectors in Africa and other parts of the world. Two generalizations from that research are the starting point for our thinking about strategic planning of agricultural research:

- Agricultural research can have high payoffs. High rates of return are most likely from relatively low-cost research that results in innovations having attributes that match the needs of the evolving food system (Oehmke and Crawford, 1993).

[1] We define NARS broadly, to include not only national agricultural research institutes, but also local agricultural universities and private-sector firms and individuals (including farmers) carrying out agricultural research.

- The value of any input depends crucially on the performance of the overall sector in which the input is used. The sector can be viewed as a *system*, and coordination of the various parts of the system determines the value of the inputs used in it.

An example of the second point is that of a high-yielding, fertilizer-responsive variety of maize. The higher yield depends on fertilizer. The payoff to research leading to an increased yield potential will be low without a reliable supply of fertilizer, of the required analysis, delivered at or below a particular price. Similarly, the performance of the economic system at many other points in the production, distribution and consumer use of maize will influence the value of the research leading to a plant variety with particular attributes.

Agricultural research can make critically important contributions to the performance of food systems and the economic development of African economies. To make the greatest contributions with the limited resources requires a planning process designed to (1) identify barriers to and opportunities for improved performance of the agriculture and food systems, (2) inform those who have to make hard choices among alternative uses of research resources by identifying likely consequences from alternative strategies, and (3) coordinate research programs with complementary public and private actions to achieve higher payoffs from the research.

The paper first defines strategic planning and describes the steps in the "business school" model of strategic planning. The paper then discusses concepts of structural and agricultural transformation and outlines how agricultural research fits into these processes. Central to this analysis is the importance of assuring *coordination of economic activities* in the economy to allow a country to break out of poverty agriculture. For activities to be coordinated in the future, various participants in the economy have to make strategic decisions in the present. Making such decisions is complicated because the future is uncertain. The paper discusses the role of strategic planning in helping guide the decisions of NARS to increase their contribution to the transformation. The paper stresses how this vision of strategic planning is related to, but different from, NARS planning efforts in the past. The final sections of the paper discuss how a strategic planning approach can be put into practice.

2. CONCEPTS OF STRATEGIC PLANNING

All organizations do some planning, and all organizations develop strategies for dealing with the future. The term "strategic planning," however, is usually associated with approaches described in an extensive literature associated with business schools. Variations of the business-school approach to strategic planning have been used by many large firms and by many other large bureaucratic organizations.

Marie-Helène Collion captures the essence of the approach by identifying the steps in a model for strategic planning (Box 1). She suggests applying this model to planning by NARS, as illustrated by the experience of IER in Mali.

Collion provides a good summary of the steps in the business-school strategic planning model. The model has many aspects appropriate to planning by public agencies as well as business firms. Steps 1 and 2 are typically referred to, respectively, as the "external scan" and "internal scan" of conditions facing the organization. Once these assessments are made, steps 3, 5, and 6 refer to developing the vision, strategy, and tactics needed to plan strategically.

The literature on strategic planning emphasizes the importance of participation of members of the organization in the planning exercise, the identification of the potential market for products, and especially the identification of strengths and weaknesses of the firm and threats and opportunities it faces in its environment. While all organizations take these factors into account to some extent, the argument for strategic planning is that large bureaucratic organizations need to go about such assessments systematically.

Yet there are two differences between the business-school approach to strategic planning outlined in Box 1 and the approach we advocate for NARS.

- The business-school model focuses on the firm. The objective of the firm is assumed to be measured by the level of benefits accruing to management and owners. The objective for a public agricultural research organization is not so simple, and this complicates the planning process. From the public's perspective, the aim is not to maximize benefits to the participants in the NARS, but to the economy as a whole. The aim, in principle, is to maximize the NARS' contribution to economic transformation, not simply maximize the welfare of the NARS.

- The standard model views strategic planning as systematically following the specified steps to develop a written plan. This approach makes strategic planning a discrete activity. It may be repeated occasionally, or be characterized by feedback loops. But in practice, in most African NARS, it tends to be done once, the report written, and the process not repeated for a few years. In adapting the concepts of strategic planning to the specific situation of the NARS, we emphasize the <u>on-going processes</u> of working out the deployment of resources to and within complex agricultural research services over time. We view strategic planning as an on-going process of problem solving—of identifying

Box 1. The Conventional Approach to Strategic Planning

Step 1. **ASSESS THE EXTERNAL ENVIRONMENT**. This encompasses five specific tasks: (a) evaluation of the economic, sociocultural, and political conditions that affect the organization's functioning and ability to achieve its goals; (b) assessment of needs of clients and interests of stakeholders; (c) evaluation of trends affecting domestic and international markets; (d) analysis of major scientific and technological breakthroughs and implications for future research; (e) analysis of other organizations' activities and comparative advantages.

Step 2. **ASSESS THE ORGANIZATION'S CURRENT STATUS.** This involves two tasks. The first relates to the organization itself, in order to formulate a strategy that builds upon strengths and overcomes weaknesses. Several aspects are important: the interests of scientists, managers, and members of the governing body; the culture of the organization; its mission and guiding values; and past achievements, capabilities, and limitations.

The second task is to assess the effectiveness of the current strategy: the organization's mission and guiding values, and the appropriateness of the current strategy in light of the organization's resources and capabilities.

STEP 3. **DETERMINE THE DESIRED FUTURE STATE OF THE ORGANIZATION.** What should the organization look like five or 10 years from now? What products or services should it propose, and for what clients?

STEP 4. **CONDUCT GAP ANALYSIS.** The gap between the organization's current status and its future, desired status is analyzed in terms of resources, capabilities, organization and structure, and guiding values. This leads to the development of a future strategy, which includes a clear definition of the organization's clients, mission and guiding values, goals, major strategic directions and issues, and priorities, as well as the resources needed to implement the chosen course of action.

STEP 5. **DETERMINE THE STRATEGY** to go from the present to the desired future state of the organization (activities, resources, and the way to combine them).

STEP 6. **FORMULATE AN IMPLEMENTATION PLAN** that operationalizes the strategy over the medium term. This should detail needed organizational changes together with the resources required and their timing.

STEP 7. **IMPLEMENT THE PLAN.**

STEPS 8 & 9. **MONITOR, ADJUST, AND EVALUATE THE PLAN.**

Source: Collion 1993

and choosing among sequences of activities leading to

different intermediate outcomes in seeking to achieve the general goals worked out for the organization. There is a practical need for policymakers to make decisions at a point in time, for a period of time, however. Otherwise there is a risk that the NARS will spend all of its time planning rather than implementing. To avoid this trap, we distinguish between decisions about national- and program-level priorities, which can be made at a point in time and reviewed periodically, and the development of specific activities at the program level. Program-level activities can be much more flexible, responding to evolving conditions in the food system.

> Furthermore, planning takes place at many levels of an organization and by many units at the same organizational level. Strategic planning as a process includes developing strategies for coordinating research plans and paths of different units of the organization to focus on solving problems consistent with the vision of the organization.

In short, we define strategic planning as the processes of working out a vision of desired outcomes, strategies for achieving the general objectives of the vision and the tactics to implement the strategies while dealing with the contingencies of the uncertain world. To be useful, a strategic planning process works out objectives, strategies and tactics that are realistically related to the resources potentially available to the organization.

3. AGRICULTURAL TRANSFORMATION AS A VISION TO GUIDE THE RESEARCH STRATEGY

All strategic planning includes at least three key elements: a *vision* of where one wants to go, a *strategy* that relates how key actions must work together to achieve the vision, and day-to-day *tactics* to implement the strategy.

The vision that needs to lead agricultural research is that of a transition from low-income, low-productivity, subsistence-oriented economies to something much better. "Something better" may be very different from the economies that have evolved in the West. Yet historically, every major country that has substantially improved real incomes has done so through a ***structural transformation*** of its economy involving:

- A process by which increasing proportions of employment and output of the economy are accounted for by sectors other than farming. The economy becomes less agriculturally oriented in a relative sense, although farming and, more broadly, the food system continue to grow absolutely and generate important growth linkages to the rest of the economy. Structural transformation thus involves *a net resource transfer from agriculture to other sectors of the economy, over the long term.*

- Movement of the economy away from subsistence-oriented household-level production towards an integrated economy based on greater specialization, exchange, and the capturing of economies of scale. Many functions formerly conducted on the farm, such as input production and output processing, are shifted to off-farm elements of the economy.

  One implication of this process is that driving down the real cost of food to consumers requires increased attention to fostering technical and institutional changes in the ***off-farm*** elements of the food system. Increasing productivity at the farm level is absolutely necessary but is alone insufficient to assure decreases in the real price of food to consumers. Another implication is that for this process of structural transformation to go forward, the economy must develop low-cost means of exchange. High transaction costs in the economy can choke off structural transformation by making it too costly for people to rely on the specialization and exchange necessary to take advantage of the new technologies in the food system. The key to low-cost exchange is coordination, that is, the matching of supplies and demands at prices consistent with sustainable costs of production.

- Increased access of individuals to knowledge systems of the wider world, as embodied in new technologies, management practices, and institutions. In the modern world, the sources of economic growth depend increasingly on these types of embodied knowledge rather than the traditional factors of land, labor, and capital. Agricultural researchers in developing countries are part of the global system that produces and diffuses such knowledge.

Thinking strategically about the role of technological change on agricultural and structural transformation therefore requires attention to two broad types of complementarities. First, there is strong complementarity between the agricultural and non-agricultural sectors. Poor performance of the systems of coordination within and across sectors appears to be the major general barrier to continued economic growth. The transformation from low-income agricultural economies involves increasing productivity in farming through farmers acquiring science-based inputs from the rest of the economy in exchange for farm products. The transformation works if the system of coordination is effective in delivering the required inputs, including food and other consumer goods, to the farming sector, and providing labor markets and off-farm enterprises to employ the labor not required for farming in more productive activities. Second, there is strong complementarity between technological change and changes in institutions and policies needed to foster greater integration, intersectoral resource transfers, and exchange within the economy.

The value of the outputs of the specialists in agricultural research will depend upon how well these outputs fit into the economic system and contribute to the development process, especially the basic agricultural transformation. Assuring a "good fit" requires strategic planning.

3.1. Sector Analysis: A Framework for Viewing the Role of NARS in Agricultural Transformation

In this section, we present the use of sector analysis as one way of simplifying the analysis needed to guide strategic planning. A key concept in sector analysis is that of coordination.

Start with the concept of a production-distribution-consumption sequence (PDCS) with two basic units of observation: physical transformations and transactions. Physical transformations are the result of combining two or more inputs to make an output. Transformations are linked by transactions. For each technologically separable transformation in a PDCS, potential transactions exist for passing outputs from one transformation activity to another. Figure 1 illustrates a portion of one PDCS. The outputs from fertilizer manufacture (PT1), the on-farm production of labor (PT2) and animal power and manure from on-farm livestock production (PT5) are brought together (through transactions) in the on-farm production of maize (PT3). The maize grain and stalks produced, in turn, may be sold or given as an input to the subsequent production of maize meal (PT4), dairy or meat products (PT5), or additional on-farm labor (PT2). Livestock feed is another product of maize milling (PT4) and an input to on-farm cattle production (PT5).

With each separable transformation specialization is possible. That is, in theory, each separate transformation can be handled by a separate individual or group of individuals. These various groups are then linked by transactions, which can take place within firms or across markets, as specialization can take place within firms or between them.

The abstract concept of the PDCS is of a series of transformations from beginning of production to the disposal of the waste following the use of the final consumer product. Each transformation is connected to the next in the sequence by transactions (Figure 1). This image is

a great over-simplification, however, when the sequences leading to the inputs to each of the transformations are also considered.

An economy can be defined as a system of interrelated PDCS. A modern economy is thus enormously complex. While keeping in mind the complexity of the economy as a system where everything is related to everything else, for analytical purposes, simplification is necessary.

As shown in Figure 1, a PDCS involves a series of interlinked physical transformations. Fostering structural transformation requires increasing the productivity of the food system PDCS. The productivity can be increased in two interdependent ways: raising the productivity of the individual transformations in the PDCS through technological change and improving the coordination among the individual physical transformations.

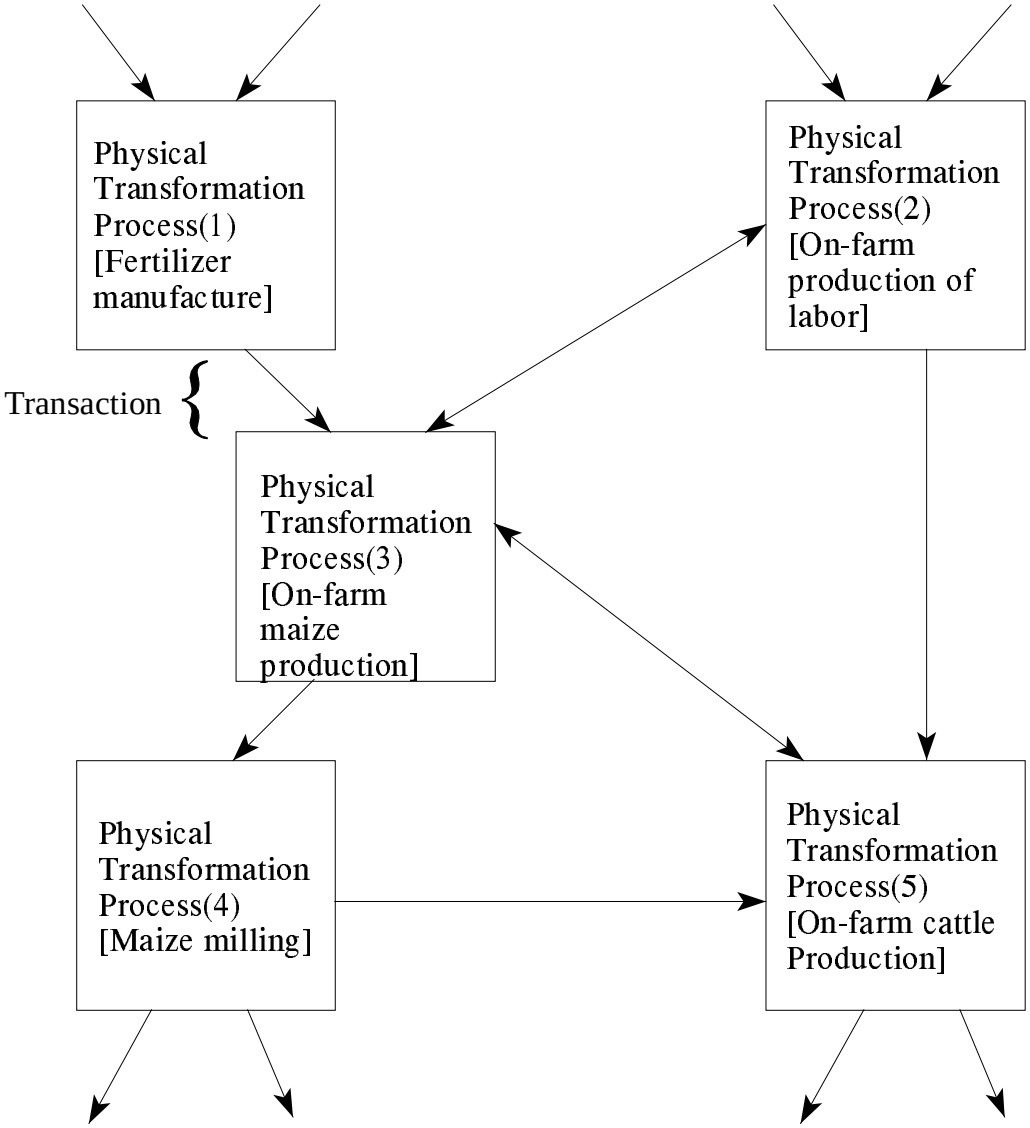
Increasing the productivity of individual physical transformations and improving coordination are, in practice, highly interdependent. In much of the food system, the physical transformations are time-dependent. Fertilizer applied at the wrong time in the growing season may lower rather than raise grain output. Thus, capturing the improved productivity made possible by the development of a new fertilizer-dependent variety requires adequate coordination between input providers and farmers. Similarly, improvements in transport and information technologies may help improve coordination. In short, technological improvements and improved coordination can be seen as two sides of a coin needed to increase productivity and foster structural transformation.

3.1.1. Technological Change as a Process of Generalized Capital Accumulation

Johnston and Clark (1982) discuss economic development as a generalized process of capital accumulation. They define capital broadly to include not only physical capital, such as irrigation systems, but also new technologies, human and institutional capital. These various types of capital tend to be highly complementary with one another, so that capturing the benefits from one type (e.g., a new irrigation system) may require adequate investment in the others (e.g., improved varieties and better techniques for irrigation system management).

A key type of Johnston and Clark's "capital" is new biological and physical technologies. These can be thought of as new inputs into the physical transformations (PTs) shown in Figure 1 (e.g., new seeds) or new knowledge about how to combine existing inputs in a different way (new production processes) to yield greater output. Improving the institutional and human capital of NARS aims at improving their capacity to generate such improved physical transformation processes.

Figure 1. Nodes in a Production-Distribution-Consumption Sequence (PDCS)



Each node in the PDCS represents a physical transformation process that combines two or more inputs (which are themselves outputs from "upstream" transformation processes) to produce an output. This output serves as an input to subsequent "downstream" transformation processes. The nodes in the system are linked by transaction, which can take place either within a firm or between firms (e.g., through markets). Examples of physical transformation processes are shown in brackets.

3.1.2. Coordination

A central problem of any economy is the coordination of activity of the systems of PDCS. The successive transformations must be linked. The connection is made by two classes of transactions - those within firms and those across markets. At least four levels of economic coordination are important to consider: (a) coordination within firms and households; (b) coordination between firms, and between firms and households; (c) industry-wide supply-demand coordination; and (d) coordination of economy-wide aggregates (Box 2). Assuring these levels of coordination is a basic challenge of economic development.

Agricultural research produces various technologies and practices that are inputs into production processes in the broader economy. The critical point here is that the payoff to these inputs depends on how well coordinated they are with the supply of other inputs necessary to the production process. Understanding coordination processes, how the outputs of the agricultural research system fit into them, and how coordination can be improved are at the heart of strategic planning for agricultural research.

3.1.3. Governance

The coordination and performance of a food system is profoundly influenced by the rules of the economic game - the governance system. The value of inputs and outputs, including the value of knowledge, is a function of the rules of the game.

The reason that the governance system is so important is because, in practice, coordination gets worked out through transactions. Participants in the economy engage in transactions in response to the participants' perceived opportunities. The options available to a participant and the benefits and costs associated with those options are determined by:

- the potential physical transformations available (the technology available to the individual—e.g., whether the individual has access to an irrigated rice system that will transform fertilizer into grain at a certain input-output ratio),

- the distribution of prices resulting from past transactions, which determine the values attached to the inputs and outputs, and

- the rights and regulations facilitating and restricting participant choices and relationships (e.g., what rights do farmers have if someone sells them "fertilizer" that turns out to be sand?) The rights and regulations consist of a combination of laws and formal regulations as enforced by government agents and the accepted codes of conduct enforced informally by groups. What is exchanged in transactions across markets are a set of rights to use something for some purposes, and the rules defining those rights obviously affect the willingness of people to engage in exchange.

Box 2. Levels of Economic Coordination

Level 1: Within firms and households.

Transactions within firms are worked out among the members of the firm based upon some hierarchy of authority. The firm adopts or develops plans and standard operating procedures to govern its members' activities and thus the linkage among transformations. Each transformation is governed by a combination of nature's design and a plan (design, formula), worked out or adopted by the firm. The firm then has some procedures or plan for allocating resources to each transformation activity and for moving the outputs of each step along the sequence leading to what the firm identifies as its products.

Level 2: Between firms and firms and households.

Transactions across markets link transformations in the sequence between firms and between firms and ultimate consumers in response to prices, promises and expectations. At each link in the sequence that crosses a market, the output-input is valued. The relationship between prices and costs of production send signals to the selling firm. The problem with this form of coordination is that production plans are based upon expected prices for inputs and products, and expectations may be quite different from market outcomes. The uncertainty can be reduced by agreements in the form of formal contracts for a future delivery or by less formal arrangements expressing intentions.

Coordination by market transactions face a number of problems in matching supply with demand. The problems involve matching attributes and matching quantities.

The importance of matching technical attributes in the sequence of manufacturing machines is obvious. Nuts have to fit the bolts, electrical plugs must fit sockets and the like. The same is true of biological processes, but the congruence in matching is less transparent. For example, there is an optimum match of the attributes of a seed variety and fertilizer formula, but the match depends on other conditions than just the seed and the formulation. The optimal match is seldom transparent to farmers.

Still more difficult is matching input attributes with desired outputs in a set of transformations that occur within households. We call these transformations "consumption," but conceptually they consist of rolling sequences of transformations from inputs to outputs. Inputs are transformed into dishes that make up meals, which are transformed to energy and attributes of health, etc., which in turn are important inputs in the transformations involving human activity. The coordination task of markets is matching attributes of products with those consumers are willing to purchase at prices exceeding the costs of production. Prices result from market transactions of existing goods, but provide no information about desired attributes that are not offered in the market. Prices also identify desired attributes imperfectly because consumers are often unable to specify the desired attributes in the products they purchase. The products with attributes leading to good nutrition and health, for example, are not transparent to many household mangers.

(Box continued on next page)

Box 2 (Continued). Levels of Economic Coordination

Level 3: Industry-wide supply-demand coordination.

The third level of coordination problems is matching quantities of commodities and products supplied with those demanded at prices consistent with costs of production. Individual firms may get the attributes right but collectively fail to match supply with the total demand. Producing too much wastes resources. Producing too little misses the opportunity to use resources where they can best meet society's needs. There are many reasons for this coordination failure. The problem of coordination at this level is complicated by (1) the long time period often required between investments in productive capacity and the delivery of the outputs; (2) the fact that collective action by the firms in an industry to match supply with demand has the potential for the extraction of excess profits resulting from restricting output; and (3) especially for farm commodities, the great uncertainty about the expected level of supply, due to uncertainties related to weather, pests, etc., and the difficulty of predicting the production decisions of other suppliers operating in a very uncertain environment.

Level 4: Economy-wide aggregates.

The fourth level of coordination is not within the scope of food systems but critically influences the performance of the food system. This coordination problem is to manage the monetary-fiscal system of the economy and to facilitate capital and labor markets in a way that results in a desired level of inflation and full employment of workers and productive assets. The transition from poverty requires off-farm employment opportunities, which requires investments, which require some minimum level of predictability in the value of the currency. The existence of unemployment is an indicator of a failure in economic coordination. Labor and capital markets fail to match the unutilized or under-utilized labor and other resources with the needs and potential demand of people.

The prices received for commodities and products are highly dependent upon the value of the currency (inflation-deflation), and market development is influenced by the purchasing power of potential buyers. Productivity, on farms and off, requires the investment of labor in the roundabout processes of production, which depend in turn on the incentives to make investments, which in turn depend on the effectiveness of the capital and labor markets.

Some understanding of the governance system is therefore critical to developing technologies that "fit" with the broader political-economic situation. For example, identifying barriers to contracting between farmers and grain processors and mobilizing support to remove those barriers may be critical to increasing the payoff to research on improved maize varieties in Mali (Boughton 1994).

3.2. Making the Vision Operational

The vision or purpose of a public research organization is not something that can be worked out by the researchers or their leadership on their own. As a public agency, often within a ministry, the research organization operates under a charter or mandate, formal or informal. Usually, the formal mandate is to contribute to the well-being of citizens of the country through research that improves the performance of the country's food and agricultural sector. This, of course, leaves a good deal to be worked out in defining the specific objectives consistent with this vision. More importantly, the organization must respond to expectations of the political system and deal with the reality of the battles over responsibilities and funds (turf battles).

In going from this general mandate to an operational plan, the research organization faces two challenges. First, it must define more precisely the aims of its research program and the assumptions underpinning it. Second, the researchers must come up with a way of describing and analyzing the complexity of the food system in a manageable way.

3.2.1. Defining Objectives and Underlying Assumptions

In developing an operational research program, the research staff must grapple with defining the dimensions of performance of the research system, and through it the food system they seek to improve. They should also define who the clients and stakeholders of the research system will be. In addition, the researchers will also need to make assumptions about what policy and economic conditions will prevail in the future, as these will strongly influence the payoffs to different paths of research.

Defining the Dimensions of Performance: The broad mandate or charter of the research organization will set out broad goals for the organization. Developing a workable plan, however, demands much more specificity about which aspects of the performance of the food system or the broader economy the research organization will seek to improve. For example, will the research focus on increasing the total value of agricultural output in the economy, regardless of where it is produced (an "efficiency" goal)? Should greater weight be given to increasing the productivity of crops grown by the poor (an income distribution goal)? How should the various dimensions of performance be weighted in deciding the allocation of the research organization's resources?

The literature on economic performance usually identifies at least three important dimensions of performance: efficiency, equity, and progressiveness. Efficiency criteria, for example, are used

in estimating rates of return to research investments. Progressiveness deals with the rapidity with which the system adopts productivity-enhancing new technologies and institutional arrangements. In recent years, sustaining the natural resource base has also frequently been included as an important dimension of food-system performance.

In practice, strategic planning has to take into account potential tradeoffs among these criteria. A research organization typically works out research programs based on a hierarchy of goals intended to improve the welfare of the people in its country by improving the productivity of physical transformations and the organization of food and agricultural production. The goals include improving food security through helping assure adequate food availability to meet minimum standards of nutrition. Some attention has to be paid to the possible tradeoff between short-run and long-run benefits; thus sustainability and degradation of environment are considered. Politically, food prices are a critical indicator of system performance. The goal should be to drive prices down for consumers and drive up profitability for farmers, while not destroying the effectiveness of the system that coordinates resources for both farmers and consumers.

Both the charter of the research organization and general guidelines from directors of the research system and various ministries will give some guidance regarding the dimensions of performance to emphasize in the research program and the relative weights attached to each. This guidance, however, does not remove all such decisions from the hands of the researchers. In practice, the weights given to different dimensions of performance will always be worked out implicitly in the process of planning specific programs of research. This is because the nature and magnitude of the tradeoffs among objectives only become evident in the context of specific research activities.

Defining Stakeholders and Clients: Defining the clients and stakeholders for the research organization involves determining whose preferences count in the design of the research program. A *client* is an intended recipient of specific agency benefits. At least since the rise of farming systems research, there has been a tendency to think of farmers as *the* clients of agricultural research. According to this view, performance of the research system should be judged on the basis of the benefits farmers receive from using the results of research.

Improving food security and food system performance, however, requires increased productivity throughout the food system, not just at the farm level (Staatz 1994). For example, if, as is typical in many African countries, marketing costs account for over 50% of the final consumer price of food, then a 10% reduction in marketing costs is equivalent to a costless 10% yield increase. This suggests that if the aim of agricultural research is to boost productivity in the food system, the clients of the research are much broader than just farmers. They include merchants, processors, input suppliers, and consumers (Boughton, Staatz, and Shaffer 1994). Even if researchers consider farmers the primary clients and stakeholders, their interests are best served by improving the performance of the larger system.

Stakeholder is a broader concept than that of client. It includes those who have a stake in what the organization does, whether or not they are the *intended* recipient of the agency's benefits.

There is a tendency among all bureaucracies to consider the management and selected employees as the most important stakeholders. One of the difficulties in strategic planning is that stakeholder and client interests may diverge. For example, researchers in the organization may want to pursue a line of research in which they have particular expertise, even though clients' needs would be served better by allocating those research resources to another area.

Just as the research system must decide which weights to give to different performance dimensions, so too must it work out how to weight the interests of different clients and stakeholders. Even if farmers are identified as the primary client, which farmers should be served? Those with large irrigated farms, or farmers with small upland plots? As with defining performance objectives, the mandate of the organization and general policy statements from on high may provide some guidance. But in practice, it is in designing concrete projects that these tradeoffs get worked out.

Framing the Research Problem: What to Assume about the Future? The objective of strategic planning for NARS is to improve the probability that research resources will be invested where they will have a high payoff. The planning therefore involves making educated guesses about where research will be most productive. Yet estimates of the payoffs to different lines of research depend critically on what one assumes about the political-economic conditions that will prevail in the future.[2] For example, whether developing high-yielding, fertilizer-responsive varieties will seem to have a high payoff depends in part on what one assumes about the future availability of fertilizer at the farm level. Can a low-cost distribution system be developed? If so, at what cost, and how do those costs affect the payoff to this line of research?

In considering these issues, researchers can make at least three different broad sets of assumptions. Which set of assumptions they choose will critically influence how they go about designing their programs and what the payoffs to those programs will be.

- Researchers can assume that current political-economic conditions will continue unchanged. This approach says that the research program should adapt to current conditions regarding, for example, the availability of purchased inputs, opportunities in export markets, and the overall policy environment. For example, Spencer and Badiane (1994) argue that capital constraints preclude most of sub-Saharan Africa from achieving the levels of infrastructure development that proved so critical to the success of the Green Revolution in South Asia. They therefore argue that agricultural research in Africa should pursue technologies that are much less intensive in purchased inputs and much less reliant on external markets than was the case in Asia.

- One can assume that political-economic conditions will change in the future, and that predictions can be made about how those conditions will evolve. The research program will then be designed to take advantage of the predicted conditions in the future. For example, researchers may predict that public infrastructure investments and policy

[2] By "political-economic conditions" we mean the general policy environment as well as overall macroeconomic and sectoral conditions.

reforms will create a conducive environment for private seed companies to invest in the country. This may make the payoff to developing hybrid seeds more attractive than focusing on open-pollinated varieties. This set of assumptions sees the future as dynamic, but not malleable by the research system itself. Researchers design their programs to fit predictions concerning the future economic environment, but the researchers don't attempt to modify that environment as part of their research program.

- Researchers can assume that the future is both dynamic and malleable. This approach is proactive and assumes that the strategic planning process will:
    - identify changes in the political-economic conditions that could increase the payoffs to particular lines of research (e.g., reforms in fertilizer import policy that could increase the returns to the development of particular varieties); and
    - help mobilize support to change those conditions. For example, by showing the potential returns to fertilizer-responsive varieties, the researchers may be able to demonstrate the payoffs to policy makers of reforming those policies (CIMMYT Economics Staff, 1984, p. 369).

The approach to strategic planning we present below is consistent with this third approach. The approach does not say that the future will be whatever the researchers want it to be. But it does see the agricultural researchers as having an influence over how the future political-economic environment facing the food system evolves. *Adopting this perspective also means that policy research becomes an integral part of agricultural research programs.*

3.2.2. Description and Analysis: The Food System Matrix

Contributing to improved performance of an economic sector requires an understanding of the sector as a system. Understanding starts with description. However, detailed and comprehensive description of any national food and agricultural sector is not feasible. For example, it is literally true that thousands of specialists coordinated by thousands of transactions contribute to the production and distribution of a single loaf of bread delivered at a grocery store, if all inputs are traced. Thus, the problem is to identify the most useful description for the purposes of identifying potential opportunities to improve performance of the sector.

One way to visualize the food and fiber sector is as a food systems matrix. The matrix is multi-dimensional, and can be viewed as a series of overlaid 2-dimensional matrices.[3] Figure 2 shows one two-dimensional representation of the matrix, with commodities depicted as columns and various stages in the vertical transformation process depicted as columns.

Research and extension (TDT - Technology Development and Transfer) can make contributions to all the production and distribution functions shown in the various cells of Figure 2. For

[3] Each two-dimensional matrix is a projection of the n-dimensional matrix into a given two-dimensional space.

example, research on grain wholesaling and urban consumption patterns may be central to discovering ways of increasing the productivity of the food system. Such research is thus legitimately in the purview of NARS.

Historically, agricultural research has focused primarily on problems that fall into individual cells—e.g., farm-level production constraints for millet. However, both farming systems research and subsector approaches (described below) address problems that span the various cells in the matrix and analyze how a coordinated approach to research to problems in different cells can increase the productivity of the TDT system. For example, research on urban consumption patterns for coarse grains may lead to major insights about the attributes that breeders need to stress in their selection programs (Boughton, Staatz, and Shaffer, 1994). Hence, research and extension need to address both physical transformations (represented by individual cells in the table) and the coordination among those transformations.

The design question this paper addresses is how to chart the strategic planning process (and hence, to some extent, the structure and function of the research system) to address these challenges in the most effective way.

The food systems matrix identifies classes of important relationships in the sector viewed as a system. The matrix helps to identify questions and data relevant to evaluating the probable value of alternative programs of research and related programs, by directing attention to important relationships in the system likely to be influenced by the research. The matrix is also useful in structuring inquiry, leading to the identification of barriers to improved performance and unexploited opportunities, thus identifying potential opportunities for high-payoff research and complementary programs. There are at least four cross-cutting constructs (areas of study) useful for organizing information to make projections, diagnose, and analyze food and agricultural sectors. Conceptually these are different ways of slicing an economic sector for examination. Consider them as four ways of slicing the multi-dimensional food systems matrix.

Commodity Subsectors: We start with agricultural commodity subsectors. *Subsectors are defined as the sequence of activities contributing to the production, distribution and use of particular commodities.* The subsector is depicted as a vertical slice in the matrix displayed in Figure 2. The emphasis in subsector analysis is on description of the vertical sequences in production and distribution and their coordination, e.g., from the point where a commodity is produced on farms until it loses its identity in meals or in industrial processes. The scope of a subsector definition is pragmatic. In the case of a crop, it could start with development of the seed varieties and end with the uses in households. It is often useful or economical to group commodities that have similar PDCS, such as the foodgrain subsector, the livestock and meat subsector, and the beverage crops subsector.

Initial description of the subsector diagrams the channels and transformations of the commodity, followed, where possible, with data indicating volumes and values of the commodities in various forms as well as costs, by source, as the commodities pass through the different stages and channels in the sequence. Most importantly, the analysis focuses on the processes of

coordination throughout the vertical sequences and on identifying problems and opportunities to improve performance.

Input Subsectors and Markets: A comprehensive description of a food and agricultural sector would include nodes for each stage in the sequence of a commodity subsector, with a description of the input subsectors for every input or relevant missing input for that transformation (Figure 1). One way of thinking about this is to envisage a third dimension rising out of the two-dimensional matrix shown in Figure 2. For example, one horizontal slice in that matrix is "transportation." Yet transportation itself requires various inputs and produces various outputs, and hence can be viewed as a subsector.

Figure 2. Food System (Agricultural Sector) Matrix

RESEARCH & EXTENSION

PRODUCTION AND DISTRIBUTION FUNCTIONS	SUBSECTORS						
	Millet	Sorghum	Maize	Cotton	Rice	Peanuts	...
Input Distribution	SUBSECTOR APPROACH						
Farm-Level Production		FARMING SYSTEMS APPROACH					
Processing							
Storage							
Assembly							
Transportation							
Wholesaling							
Retailing							
Financing							
Consumption							

Since at least every purchased input is based in turn on another set of inputs, and they, too, on another set, etc., the complexity of such a system quickly exceeds capacity for meaningful description. Nonetheless, some input subsectors will be of critical importance to the performance of the food sector. Examples may include fertilizers and other farm and processing chemicals, transportation, and packaging materials. Coordination failures upstream in specific input subsectors often have a critical influence on the performance of commodity systems.

Knowledge is an especially important and complex input. Understanding the knowledge subsector at some level will be particularly important in strategic planning for an agricultural research agency. How, for example, is knowledge transformed into outputs of economic value when applied to different uses?

Food also serves as an input to agricultural production, through its effect on nourishing workers and influencing wage rates. The role of food as an input is often neglected, with food being treated solely as a consumer good. The evidence is that productivity is highly related to food availability (Vogel 1994).

Monitoring land and labor availability and use as system inputs is also central to planning. Land is especially important in farming, and labor is important as an input in every transformation. Analyzing land and labor as inputs on a subsector-by-subsector basis would miss identification of important problems and opportunities. The process of transformation from low-input, low-income agricultural economies depends on shifting labor out of farming.
Planning decisions based upon static perceptions of the labor market can contribute to stagnation. For example, many research programs that increase labor productivity in farming would be undervalued if judged on the basis of static estimates of the limited availability of off-farm employment for those released from farming. In the perspective of a dynamic system, which includes research effectively addressing the problems of unemployment in the transformation process, the value of such productivity enhancement could be high. This example illustrates the importance of the strategic question of how NARS view the future (and their role in shaping the future) and how their activities fit into a larger system of public and private planning and policy.

Industry Studies: Subsector studies examine the coordination of activity in the sequence of production, distribution and consumption of particular commodities, products or inputs ("vertical slices" in Figure 2). Industry studies examine the performance of firms in the same line of business ("horizontal slices" in Figure 2).

As was true for a subsector, the scope of the definition of an industry will depend on the purposes of the inquiry. For example, farming could be treated as a single industry, or maize farming, or retailing. Emphases in industry studies include within-firm coordination, between-firm competition, and coordination of supply and demand at the industry level.

It is useful to analyze the performance of industries as well as subsectors for at least two reasons. First, different perspectives yield different insights into how the food system works. For example, an industry approach may lead to new insights into how prices for grain are set at the

wholesale level, taking into account how merchants link pricing decisions across different products. Second, it may be more cost-effective to analyze certain questions from an industry, rather than a subsector, perspective. For example, food retailing is important for most commodities. While there may be unique problems related to retailing for maize and maize products, understanding those problems would be greatly facilitated by a more general study of the food retailing industries.

To date, agricultural research in Africa has concentrated on farming. Farming systems research is largely the study of coordination within farm firms. Farming systems research, one type of "industry study," provides very important information for research planning and should be an important part of any systematic agricultural sector analysis.

Economic Coordination Services: There are several classes of what we call "coordination services" that can greatly influence the effectiveness of the coordination of resources, thereby affecting the performance of the sector and hence the value of alternative research programs.

The identification and enforcement of rights and obligations. As already discussed, transactions across markets are facilitated by this function of government. At the same time, these rules influence values of inputs and outputs and thus will have to be considered in assessing the returns to alternative lines of research. Also included for analysis would be government subsidies, taxes, price fixing, rules on competition, food safety law and enforcement, etc. For example, if the value of a commodity is lower than it otherwise would be because of monopoly in importing food processing equipment, what price should be used in the ex-ante appraisal of the research to increase production of the commodity? Should the research include analysis identifying ways to deal with the monopoly?

Finance. The credit and banking system deals in contracts that create rights to use resources. Credit clearly has a great deal to do with the use of purchased inputs and investment in productivity-enhancing practices. Credit decisions influence coordination at all four levels shown in Box 2. Credit decisions ration the use of inputs and influence the value of outputs at every stage in the transformation process. At the industry level, over-production and under-production of a commodity will be greatly influenced by credit decisions.

Since the banking system creates money, its practices influence the value of money and the coordination of aggregate supply and demand for the economy. Because the credit system creates money, it not only decides on the allocation of savings but also, in effect, takes resources from some and lends them to others. It creates rights to resources. How it functions thus has important equity implications.

Because of the way labor markets work and the barriers to expansion of off-farm enterprises, unemployment is endemic in less-developed countries, greatly inhibiting the transformation from poverty agricultural systems. Both micro credit decisions and aggregate lending have the potential to promote the transformation by creating demand for inputs and outputs and facilitating access to resources by those in the best position to use them to meet the expanded demand. However, failure to coordinate aggregate money supplies effectively with the supply of

goods leads to inflation and disruptive effects on investments, production and stocks. The failure in many African countries shows up as a combination of high unemployment and high inflation--stagflation.

Risk Management. Insurance and institutions for risk management are another set of important services facilitating economic coordination. Poor performance or absence of these services is a barrier to making some investments, increases transactions costs, and inhibits the transformation. The transformation to a more market-oriented economy is facilitated by improvements in the predictability of outcomes and the protection against some adverse consequences. Potentially useful services that could be analyzed as part of a research/action program include traditional property insurance, guaranteed warehouse receipts, title insurance, futures markets, crop and revenue insurance, and forward deliverable contract markets.

Information. Transactions and planning are obviously highly dependent on information services. Since many types of information have public goods characteristics (the added cost of an additional user is zero or slight and the cost of excluding a user is high), there is a high propensity to under-invest in information services. This has special implications for a publicly funded research organizations. For example, do farmers have access to reliable and timely market information and the skills to use it in a way that will allow them to profit from a new cash-crop variety? If not, what complementary marketing or extension activities need to accompany the release of the variety?

The Role of Agents and Networks. Transactions, within firms or across markets, are made by people acting as agents for firms, households, government organizations, and possibly associations. Effective coordination of complex food systems depends upon networks of agents generating information and working out solutions to coordination problems. Innovation is the hallmark of the processes of development, and networks are particularly important in achieving adoption of innovation. Networks of vertically related agents may be critical, for example, in gaining adoption of a new variety requiring specialized inputs, unique transportation, a new food processing technique, a change in regulation and different uses in meal preparation. The absence of any one of the adjustments in the vertical sequence may render a potentially useful innovation useless. Therefore, understanding the functioning of such networks may be an important part of the research program.

4. LESSONS FROM EXPERIENCE

Two major findings of recent research impact studies carried out by MSU were that (1) agricultural research can have a high payoff, and (2) the impact of research depends critically on the performance of the larger food and fiber system. Rates of return from these studies are presented in Table 1. This section summarizes the most important lessons from the research impact studies in the context of the framework developed in the preceding section. Specifically, we address the following questions: (1) what factors influenced adoption of technology in the study countries? (2) in cases of successful technology adoption, have the investments that contributed to it been sustained? and (3) what role did research planning play in bringing about "success" stories?

4.1. How Capital Investment and Coordination Affected Research Impact

Figure 1 described the production-distribution-consumption sequence (PDCS) as nodes of physical transformation (combining two or more inputs to make an output) that are linked by transactions. An example of one physical transformation (PT) node is the development of improved varieties by breeders. Inputs to that process include germplasm, the human capital of breeders, entomologists, soil scientists, extension agents, and so on. Production of a commodity by farmers themselves is another PT node, which is linked to the "improved technology development" node. Inputs to the production PT node include improved seed, fertilizer, and recommendations from the extension service. Commodity processing (e.g., maize grain into flour) constitutes a third PT node: the commodity itself, processing equipment, and knowledge about how to operate the equipment are important inputs. In the MSU country studies, cases where research achieved the greatest impact were distinguished by the availability of capital, and then the coordination of transactions, that first brought together inputs to the "improved technology development" PT node. This was followed by success in coordinating the rolling sequence of capital investments and transactions that brought inputs to successive PT nodes—production, processing, and so on—at the right time.

4.1.1. Accumulation of Capital and Coordination within the Research Subsector

In countries where NARS successfully developed or adapted technology, (1) human and physical capital resources were in place; and (2) these inputs were successfully coordinated by the NARS. Scientists had the training, equipment and incentives to seek out and utilize promising germplasm from regional or international centers, in effect extending their own limited capital resources. NARS in Mali, Cameroon and Senegal were able to borrow and adapt varieties from abroad fairly easily, saving time and expenditures by their own NARS (Crawford 1993, Schwartz et al. 1993). Zambian scientists purified Zimbabwean SR52, and also developed new hybrids based on selections from an international germplasm collection

(Howard 1994). Facilitating coordination within the NARS has also been very important. An outbreak of maize streak virus in Mali in the early 1980s prompted a combined effort by

Table 1. Summary of ROR Studies for African Agricultural Technology Development and Transfer

AUTHOR	YEAR	COUNTRY	COMMODITY	TIME PERIOD	ROR IN %
Sterns and Bernsten	1994	Cameroon	Cowpeas	1979-92	3
			Cowpeas	1979-98	15
			Sorghum	1979-98	1
Karanja	1990	Kenya	Maize	1955-88[a]	40-60
Mazzucato	1991	Kenya	Maize	1955-88	58-60
Boughton and Henry de Frahan	1994	Mali	Maize	1969-91	135
				1962-91	54
Mazzucato and Ly	1994	Niger	Cowpeas, Millet & Sorghum	1975-91	<0
				1975-2006	2-21[b]
Schwartz, Sterns, and Oehmke	1992	Senegal	Cowpeas	1981-86	31-92[c]
Laker-Ojok	1994b, 1994c	Uganda	Maize	1985-96	<0-15[d]
			Maize	1985-2006	27-58[d]
			Soybean	1985-96	<0[d]
			Soybean	1985-2006	<0-20[d]
			Sunflower	1985-96	<0-62[d]
			Sunflower	1985-2006	10-66[d]
			Groundnuts	1985-96	<0-27[d]
			Groundnuts	1985-2006	23-46[d]
			Sesame	1985-96	<0-40[d]
			Sesame	1985-2006	15-57[d]
Howard	1994	Zambia	Maize	1978-91	<0[e]
			Maize	1978-2001	42-49[f]

Source: Crawford 1993 and references

[a] Parameters estimated for the period 1955-88; rate of return calculated assuming that the research was initiated in 1978.
[b] Depending on assumptions about yield, rate of adoption, etc.
[c] The 92% rate was obtained when including the value of the early cowpea variety as a contribution to household food security.
[d] Depending on assumptions about yield, rate of adoption, and costs included.
[e] Includes costs of research, extension, production, seed multiplication, and the real costs of maize program subsidies.
[f] Includes same costs as 1978-91 calculation, but assumes maize subsidies end after 1991.

researchers from the national system (IER) and the cotton parastatal (CMDT) to study the disease and test control measures. This effort resulted in the release of a streak-resistant variety (obtained from IITA) within three years of the initial outbreak (Boughton and Henry de Frahan 1994).

Uganda provides a stark example of the difficulty and expense of rebuilding research capital from scratch. The breakup of the East African Community, arbitrary macro policies of the 1970s, and the war and civil unrest of the early 1980s severely disrupted the research system. Facilities and equipment were damaged, seed lines and trial results were lost and scientists were displaced. Rehabilitation of the research system began in 1987; the improved varieties released in 1991 were the first in 20 years (Appendix 3; Oehmke and Crawford 1993; Laker-Ojok 1994c).

The Uganda case is an extreme example of the collapse of capital resources and coordination within a research system. Disintegration can also take place more subtly, eroding research productivity. In Zambia, the development and release of maize hybrids in the early 1980s was in part the product of successful coordination between Zambian national researchers and breeders attached to two separate donor projects. This cooperation broke down in the late 1980s, resulting in the *de facto* establishment of two semi-competitive hybrid sub-programs within the maize section funded by different donors. Research productivity has been affected by these management problems, by low salaries and by an advancement system that encouraged scientists to move out of research into administrative positions. Ten varieties were released between 1984-88, but there have been only two new releases since then (Howard 1994, Munyinda et al. 1994).

4.1.2. Performance of the Input Subsector

Once technology was developed or adapted, the ability to coordinate its delivery to farmers was a critical factor in the rapid adoption of improved varieties. In Zambia, the Swedish aid agency SIDA simultaneously funded hybrid maize research and the development of a national seed multiplication and processing capacity. Hybrid seed was available to farmers in most of the country the season following its official release. In Mali and Cameroon, distribution of improved foodcrop varieties, fertilizer and other inputs was handled by cotton parastatals. These organizations had already developed effective, integrated procedures for procurement and dissemination of cotton technology that was readily transferred to another crop (Appendices 1, 2; Crawford 1993).

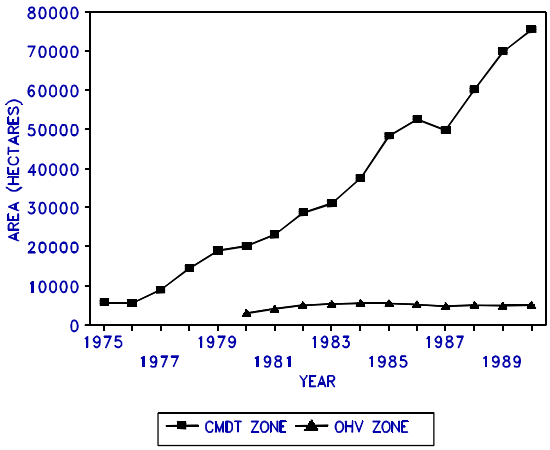
Regions that did not benefit from efficiently integrated input delivery services showed a different adoption trajectory. In Mali, adoption of improved maize in the area served by Operation Haute Vallee was flat compared to CMDT clients (Figure 3). The deterioration of input delivery services in Zambia's Regions I and III by the late 1980s contributed to a leveling-off of maize hybrid adoption there (Figure 4) (Howard 1994). In Uganda, the potential impact of improved varieties is constrained by the limited capacity for seed multiplication, especially hybrids (sunflower) and for the production and distribution of rhizobium (soybeans) (Appendix 3; Crawford 1993).

4.1.3. Coordination of Assembly, Transportation and Financing

Farmers in Mali and Zambia were also attracted to improved maize because state-supported marketing channels created new opportunities to produce maize as a cash crop. In Zambia, the easy availability of local marketing outlets for maize (but few other commodities) drew many remote smallholders into commercial production for the first time. These subsidized marketing systems proved financially unsustainable in both cases, however. In Mali, the discontinuation of guaranteed prices and credit programs led farmers to withdraw from the market and produce maize mainly as a subsistence crop. Commercialization of maize is also limited by the high cost of processing maize into flour (Boughton 1994). The recent liberalization of maize marketing in Zambia is dramatically changing the geographical distribution of commercial maize production there (Appendices 1,2).

The absence of private or government-subsidized coordinating mechanisms constrains oilseed production, marketing and processing in Uganda, and therefore the potential returns to oilseed technology. A classical vicious circle has developed: oil mill revenues are limited by the small quantity of sunflower seed marketed, while farmers market small quantities because of unattractive returns to labor and the absence of local markets (Crawford 1993; Laker-Ojok 1994a).

Figure 3. Adoption of Improved Maize in Mali's CMDT and OHV Zones



4.1.4. Sustainability of Capital Accumulation/Coordination

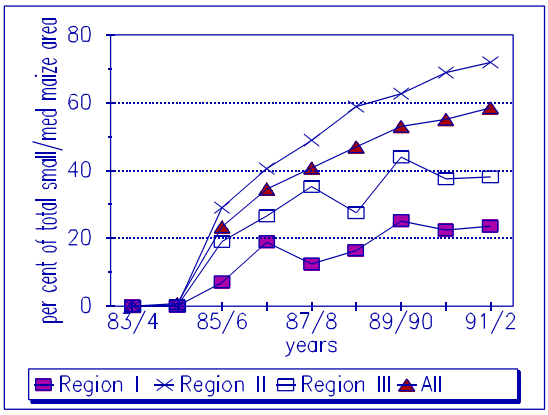
Agricultural research can and has had an impact in a number of countries, but the absence of **sustainable** coordinating mechanisms and sources of capital has been an effective barrier limiting the long-term contribution of research to agricultural transformation. The Mali and Zambia cases demonstrate how quickly new technology can spread when coordination of input and product markets is effective. However, the coordinating organizations in both cases were artificially sustained by government subsidies that became financially untenable. If processing constraints are alleviated and consumer demand for maize meal grows, production and marketing of commercial maize may become more attractive in Mali. Zambia already has a relatively well-developed urban market and processing subsector, but realignment and expansion of maize production depend on the emergence of market-driven or mixed public-private coordinating organizations (input suppliers, credit facilities, product marketing services).

4.2. Lessons for Research Planning

4.2.1. Priority-Setting Tools

The most common research priority-setting tool used in sub-Saharan Africa is the scoring method. Other tools are described in Box 3. In scoring, objectives for the research program are identified and each objective is assigned a weight to reflect its political and economic importance. Research administrators and scientists rank the research programs with respect to how well they think the program contributes to meeting a given objective. Criteria can be used to provide measures of the contributions of research to objectives. They might include (for an efficiency objective) expected value of production, cost reduction or yield increase, input cost changes, probability of research success, adoption rates, future demand, research costs. For equity-related objectives, criteria may include yield, production, price, income stability, self-sufficiency, or food safety (Alston et al. 1994). The overall rank of a research program is determined by totalling the weighted contribution of research to each of the objectives (Daniels et al. 1992).

Figure 4. Small and Medium Farmer Adoption of Improved Maize in Zambia



The great strength of scoring is that it allows consideration of multiple economic objectives without having to use a complex analytical tool such as mathematical programming or simulation. Also, simpler approximations of more complete economic surplus measures can be used. The method itself is flexible enough to incorporate quantitative projections of research impact on commodity yields or costs, value of production, etc. In practice, though, this has rarely been done, and the scoring method has become known as a fairly easy but highly subjective method lacking analytical rigor (Alston et al. 1994).

In our view, the way the scoring model has been implemented in many, but not all, cases is symptomatic of larger problems with research planning at the national and program levels. The main issues are (1) how are dimensions of performance defined, and how are contributions of alternative research programs or activities to them made transparent? (2) who are research stakeholders and clients? and (3) what should researchers assume about the future?

Box 3. Tools for Priority-Setting

Scoring, congruence, checklists, benefit/cost analysis, domestic resource cost analysis, mathematical programming and simulation are the most common methods used to analyze existing and potential research impacts. The first three are the simplest, generally involving little quantitative analysis. Simplest of all is congruence, the guiding principle being that research funds should be divided among commodities according to their contribution to the agricultural domestic product. If cassava contributes 2% of agricultural GDP, then it merits 2% of total research funds (Contant and Bottomley 1988, 11).

In the checklist approach, research planners use a list of criteria and related questions, usually centered on probable research impact, cost, and feasibility, to rank alternative research projects. The scoring method, which is the most commonly used tool for research planning, is in effect an expanded checklist with the answers to questions assigned weights (Contant and Bottomley 1988, 12).

Benefit-cost or rate of return analysis evaluates the change in economic surplus, or benefits, expected from a shift in supply due to an increase in productivity, here as a consequence of research investment (Alston et al. 1994). The rate of return (ROR) summarizes in a single number the time pattern and relative sizes of the cost and benefit streams of a research program. While more demanding of data and analytical skill than congruence, checklist or scoring methods, the economic surplus approach provides a framework for bringing together quantitative information on, e.g., the likely yield or cost reduction impact of research, the probability of research success, adoption rates, and prices to evaluate the potential impact of research. Once an ROR has been calculated, it can be compared to the prevailing interest rate or some other measure of the opportunity cost of capital. If the ROR exceeds the cost of capital, then the project is considered economically successful.

In DRC analysis, the ratio A/(B-C) is calculated, where A is the economic value of non-traded inputs used to produce a unit of the commodity, B is the economic value of gross output, and C is the economic value of traded inputs used to produce one unit. If the ratio is less than one it is economically profitable to produce the commodity. The advantage of the DRC is that it is a simple measure of the economic value of inputs needed to generate one unit of output valued at its economic price. However, the DRC analysis does not incorporate the number of units (hectares of land, number of animals) to which the benefits will apply, which is a major factor in determining the relative size of benefits from alternative research programs (Alston et al. 1994).

The basic structure of mathematical programming models is an objective function that is maximized subject to some constraints. These models maximize the total utility (benefits) of the research program, as measured by the ability of each project to achieve the research objectives at the given level of funding. Similar to scoring, weights are used to reflect the political and economic importance of a set of research objectives. The advantage of this approach, although it is data-intensive and requires a high degree of analytical skill, is that an optimal research portfolio (as opposed to a simple ranking) is selected based on **multiple** goals and resource constraints (Daniels et al. 1992).

Simulation models, like benefit-cost or rate of return analysis, also measure the change in economic surplus that results when a research investment brings about a change in agricultural productivity. Generally a three-stage process is involved. First, a model is constructed to estimate an econometric relationship based on time-series data. An index of agricultural productivity is estimated as a function of research expenditures. Second, the effect on output of varying research expenditure is computed under different scenarios. Third, this productivity change is translated into a supply curve shift followed by an assessment of market-level consequences. Like mathematical programming, simulation models optimize a research portfolio, and they also allow analysis of research effects on a number of parameters such as employment and income. However, this approach is the most demanding of all in terms of data requirements and analytical skills (Daniels et al. 1992).

Box 4. Zambia's Scoring Process: Objectives and Criteria for Ranking Research Activities

OBJECTIVE	CRITERIA
Food security	Share of commodity in consumption for the poor Contribution of commodity to income of the poor Calorific value of commodity
Income and employment	Value of commodity output Market potential for commodity Demand for extra labor
Sustainable agricultural resource base	Contribution of commodity to chemical properties of soil Contribution of commodity to physical properties of soil Contribution of commodity to biological properties of soil
Contribution to industrial development	Industrial demand for commodity Farmer demand for inputs to support commodity production
Balance of payments	Commodity contribution to foreign exchange saving through import substitution Commodity contribution to foreign exchange earnings
Suitability	Adaptability Acceptability

Source: Munyinda et al. 1994

4.2.2. Performance Dimensions

Participation in scoring has often been limited to researchers and research administrators. Often it is they who assign weights to the proposed objectives for the research program (reflecting the relative importance of efficiency, equity, and progressiveness) although this is an important political decision that should initially (at the national level) be guided from the cabinet. At the program planning level, researchers will implicitly work out the weights given to different performance dimensions in the process of planning specific programs of research, because the tradeoffs between objectives will only become apparent in the context of individual research activities.

When participation in scoring/priority-setting is confined to researchers, the economic information and analysis that is brought to bear as researchers rank activities can be very limited. During a recent scoring exercise in Zambia, researchers identified the criteria shown in Box 4

for use in evaluating the contribution of potential activities to different objectives. The complex nature of the criteria imply the need for a fairly comprehensive knowledge of each subsector in order to rank knowledgeably, even if the rankings are as simple as high, medium, and low.

One possible consequence of failing to incorporate information about the complexity of factors affecting the success of proposed research activities is reflected in the conflicting results of different priority-setting measures in Uganda (Table 2). The rankings for sesame and sunflower from the ROR base case scenario exceeded those of maize and groundnuts, which received higher rankings in the scoring method. Several factors contributed to the differences. The scoring method emphasized the average value of production of the commodity over the preceding 3 years, which favored the basic food staples and traditional cash crops. However, sesame and sunflower area, though they are now minor crops, has expanded considerably recently, and this potential is captured in the ex-ante ROR. The scoring system also considered the number of farmers whose income would be affected as a result of yield improvements in a commodity and the environmental impact of a technical change. These factors were not captured in the ROR, which measured only contributions to economic efficiency at the national level. Third, although foreign exchange savings is an important national agricultural objective, it was not included in the scoring method. Because the ROR uses shadow exchange rates to reflect the scarcity value of foreign exchange, the value of import-substituting commodities is enhanced. Finally, the scoring method did not consider the cost of research or the timing of results and adoption, while the ROR specifically emphasized both (Laker-Ojok 1994b).

4.2.3. Stakeholders and Clients

Researchers (guided by policymakers), besides determining the weights to give to different performance dimensions, must also weight the interests of different clients and stakeholders. Although farmers are the primary client of NARS, researchers must decide which groups of farmers to target. This implies that researchers should have information available to them that estimates the potential impact of alternative research activities on different groups of farmers and consumers. In Zambia, for example, it is important for researchers to know the implications for different farmer and consumer groups if they continue to concentrate on hybrid maize versus turning increased attention to alternative food and cash crops.

Researchers themselves are stakeholders in the research system whose needs must be taken into account. However, this has sometimes resulted in a concentration on areas that have scientific interest but may not meet a practical need of clients. In Niger, although farmers expressed a need for research on millet/sorghum/cowpea intercropping, scientists continued to carry out research exclusively on monocropping of cowpeas until the 1980s (Crawford 1993). In Mali, researchers failed to correct the row spacing for an improved maize-millet intercropping system despite observations by farmers that it did not permit mechanical weeding (Boughton and Henry de Frahan 1994).

Table 2. Comparative Research Priority Rankings Using the Weighted Scoring Method and Benefit-Cost Analysis

Commodity	Weighted Scoring Method Rank[1]	NARS Priority Level	ROR Base Case Scenario (%)	ROR Worst Case Scenario (%)
Groundnuts	5	high	37.1	23.1
Maize	7	high	33.2	27.3
Sesame	15	medium	42.5	15.3
Soybeans	18	low	4.8	-6
Sunflower	20	low	38.4	10.3

Source: Laker-Ojok 1994b

[1] Lower numbers indicate a higher rank.

The needs and preferences of other clients, besides farmers, are also important to take into consideration. Ugandan consumers prefer white soybeans, for example, but the only varieties produced by the research system are red in color (Crawford 1993; Laker-Ojok 1994b).

4.2.4. What Researchers Assumed about the Future

The assumptions researchers in case study countries made about future political-economic conditions and their role in the research and dissemination process made a difference to the research path chosen (delimiting potential increases in agricultural productivity) and the success of research products. Assumptions about the reliability of seed multiplication and distribution services greatly influenced the research choice between open-pollinated and hybrid varieties of maize and sunflower in Mali, Zambia and Uganda. In all three countries, hybrids have a significant yield advantage over open-pollinateds (Howard 1994; Laker-Ojok 1994b). However, farmers must repurchase hybrid seed each season because seed characteristics degenerate rapidly with replanting in successive seasons, in contrast to open-pollinated varieties. If a hybrid path is chosen, reliable seed multiplication and distribution is essential.

Of the three countries, only Zambian researchers focused on development of hybrid varieties (maize) for smallholders beginning in the late 1970s. They were confident in this approach because smallholders were already well acquainted with hybrid maize, and seed multiplication and distribution capacity was being strengthened with donor assistance (Howard 1994). In Uganda, researchers were pressured to focus on open-pollinated varieties since there were serious questions about the ability of the Seed Scheme to handle hybrid seed production. Returns to labor in sunflower production are currently too low to motivate farmers to produce the crop, however, and dissemination of higher-yielding hybrids is one way to increase returns (Laker-Ojok 1994a). In Mali, the research institute's governing board adopted a policy of not

testing hybrids because they believed the seed would be too costly, despite the lack of any financial analysis (Boughton and Henry de Frahan 1994).

The proactive approach taken by Zambian maize breeders contributed to the rapid development of maize hybrids, availability of seed and extension of technology to smallholder farmers. Hybrid maize dissemination was helped by the strong four-way relationship between maize breeders, farmers, extension and the seed company. One breeder actively promoted and solicited reactions about hybrid and open-pollinated technology from farmers and extension agents. Thus, the characteristics of the new varieties met key problems for smallholders: season length and disease resistance. Another breeder described himself as an "entrepreneur" in his dealings with the seed company, selling and shaping a product for a market. The fact that Swedish SIDA funded both maize breeding and the seed industry under one project created interdependence and helped motivate this coordination. One important result was the close relationship between the different hybrids, i.e., a core of parent varieties was combined and recombined in different arrangements, as single, double and three-way crosses, making seed production simpler and more economical (Howard 1994).

5. TOWARDS AN OPERATIONAL MODEL FOR STRATEGIC AGRICULTURAL RESEARCH PROGRAM PLANNING (SARPP)

5.1. Introduction

The objective of strategic agricultural research program planning (SARPP) is to increase the benefits to society from investment in agricultural research and hasten the process of agricultural transformation in African economies. The extent to which this objective is achieved will depend on the "goodness of fit" between farm-level technology development and complementary investment and innovation in institutions, technology and policy in the off-farm components of the food and fibre system. This section examines the questions that need to be answered to improve this fit over time, the use of a food systems matrix as a conceptual framework to organize analysis and interaction between participants in the program design and implementation process, and implications for institutionalizing SARPP.

There are two caveats we need to underscore at this point. First, SARPP is a complement to and not a substitute for strategic plans for research organizations. The latter involve considerations such as the organization's legal status, personnel management policy and training, physical infrastructure management, and financing mechanisms. Unless there is a stable and sustainable organizational structure, SARPP will be very difficult to implement. Second, SARPP needs to be grafted into the existing research management system and human capital base of NARS. Achieving this requires consideration of three sets of issues:

- What kind of information and analyses are needed to guide decision-making at different levels in the NARS?

- Where in the NARS (broadly defined) does the information and analytical capacity exist and what linkages between different organizations within the NARS (e.g., Ministry planning units, universities, research institutes) are necessary to mobilize that capacity?

- How can the participation of different client and stakeholder groups in problem diagnosis, planning and implementation be structured in a way that articulates their demands without swamping the NARS?

The approaches taken in practice will inevitably be idiosyncratic, varying with the needs and capacities of specific NARS and their regional counterpart organizations. We therefore enrich the discussion with illustrations of recent examples of research planning approaches in Morocco, Senegal, and Mali.

5.2. Key Questions to be Addressed in a Strategic Research Program Planning Process

One way to look at SARPP is as a sequence of questions that need to be answered to define the vision, strategy and tactics that will lead to a greater payoff to investment in the program. These include:

- What are the development goals and objectives for the agricultural sector, commodity subsector (or geographical region or resource) that a research organization or program is concerned with?

- What are the major constraints (in regard to technology, infrastructure, institutions and policy) to the realization of those goals and objectives, and what are the relevant boundaries for analysis of the constraint (regional, national, sub-national)?

- What are the opportunities for technological innovation at farm and/or other stages in the food system? Do the technologies exist or must they be developed, and if they exist at what level (national, regional, international)?

- To what extent are potential technical innovations dependent on or responsive to investments, or policy or institutional innovation in the food system?

- Who are the relevant direct clients (technology users), indirect clients (those other than technology users who gain or lose from adoption) and stakeholders whose participation is necessary to help define and realize the potential contribution of agricultural research?

- How should the NARS choose among (prioritize) alternative opportunities to match activities to available human and financial resources?

The difference between SARPP and conventional approaches to research planning is the use of a food systems perspective (see Figure 2) to identify the information, analyses and participants needed. A food systems perspective can help inform and better integrate two broad levels of planning:

- At the national level a food systems perspective can help, through a better understanding of the complementarity between policy, technology and private and public sector investment, to inform decisions concerning the overall level of investment in agricultural research, priorities and resources to be allocated among program areas (commodity programs, farming systems, natural resource management), and the organizational structure for the system.

In Zambia, for example, dismantling the system of pan-territorial and pan-seasonal pricing for the country's major cereal staple is resulting in significant changes in farm-level technology use and regional production patterns. What research priorities will assure rural food security and diversify income sources in areas where intensive maize is no longer profitable? For those areas where maize cultivation is profitable, what complementary investments in organizations (e.g., cooperatives) are necessary to realize potential farm-level productivity? What are the implications of trade liberalization in Southern Africa for maize prices in Zambia? This is the perspective from which Zambia's agricultural research needs to be planned to make a strategic contribution at the national level.

- At the individual (commodity, farming system or resource) program level a food system perspective can help guide the development of long-term and more detailed short- to medium-term action plans.

In Mali, a crucial question with implications for the size and strategy of the maize research program was whether the processing constraint that dampens urban demand could be overcome. Consumer tests carried out with urban households and private sector processors revealed that this was unlikely in the short run, in part because of increased processing costs following a 50% currency devaluation. Instead the maize program needed to focus on cropping systems and production techniques that reduce unit costs of farm-level production through improved efficiency of nutrient supply and use, particularly in the southern part of Mali where investment in feeder roads and mechanization is opening up new areas for cultivation.

Clearly, the development of a coherent national agricultural strategy will involve an iterative process between the program and national planning levels. For example, in the long run Mali may need to consider investment in fertilizer mixing facilities to help make intensification of rainfed cereal production an economically viable alternative to extensive cropping systems. Also, since consumer tests of maize flour indicate little improvement in substitutability between maize and rice (which supplies more than half of all urban calories) Mali may need to place a high priority on maximizing the productivity of its existing investments in irrigated rice. We now turn to some examples of attempts to incorporate a food systems perspective into research planning.

5.3. Integrating a Food Systems Perspective at the Research Program Level

Collion and Kissi (1991, 1994) present a case study in long-term research program design for the olive subsector in Morocco. The approach is helpful in conceptualizing the sequence of research planning tasks. We then consider in more detail how a food systems analytical framework can be incorporated into this sequence using simple research planning tools developed by Mali's Commodity Subsector Economics program.

5.3.1. A Case Study of Long-Term Research Program Design for the Olive Subsector in Morocco

The objective of the approach presented by Collion and Kissi is the design of long-term programs, and includes a procedure for setting priorities among sub-programs. The approach also seeks to generate information necessary for priority setting and resource allocation at the national level (e.g., potential productivity increases by commodity and agroecological zone, potential rate of adoption of new technologies, probability of research success).

The method is designed to be used by a Program Steering Committee (PSC), "an organizational device whose function is planning, monitoring and evaluating a program" (Collion and Kissi 1991, p. 38). The PSC provides a forum for researchers and their public and private sector

clients to interact during the preparation and subsequent implementation of the long-term plan, in accordance with guidelines provided by the Research Policy Committee. PSC members should represent all stakeholders, including: (1) (at the senior researcher or research manager level) public and private sector research organizations, (2) (at the directorate level) extension services, parastatals and/or private sector companies concerned with agricultural input and/or output marketing, ministries dealing with agriculture, and
(3) representatives of producer groups (including processing industries). The committee should represent national and regional levels, and be multidisciplinary. The PSC does not belong to the organizational structure (hierarchy) of a research organization, although the authors recommend that the research organization provide leadership to the PSC.

Program planning is accomplished in seven steps undertaken in two three-day workshops (see Box 5 for details). The four steps addressed by the first workshop are (1) review of commodity situation and development objectives, (2) analysis of constraints to increases in productivity, (3) review of existing internal and external research results, and
(4) determination of research objectives. After the first workshops the results are written up and circulated to PSC members. Prior to the second workshop, scientists meet to identify research areas and activities on the basis of research objectives, and to determine the human resources needed for implementation. The second workshop brings back all members of the PSC to review the first part of the program document, review research areas identified by scientists, and set priorities.

The approach developed by Collion and Kissi for long-term research programs has several strengths. It recognizes the need to combine farming systems and commodity subsector perspectives to understand relationships between technical, economic, institutional and policy-related constraints. It recognizes the need to represent different stakeholders and disciplines in the PSC, and the need to develop an approach that is efficient in the use of PSC members' high opportunity cost time. Finally, the procedure is intended to be as explicit and transparent as possible. Inevitably the approach makes sacrifices in order to accomplish the process rapidly. We first examine these weaknesses and then review the approach to see what options exist for strengthening the approach while preserving its strong points.

The approach as presented has two main weaknesses. First, the usefulness of the exercise depends critically on the depth and reliability of information available to PSC members. In practice, the quality of information and analysis available to PSC members is likely to vary greatly between countries, depending on the human capital base, stage of institutional development, and access to international information sources. In general, countries in sub-Saharan Africa are likely to face much more severe information and analysis constraints than Morocco. Thus, there will often be a need to identify major information gaps or undertake additional analyses to be able to make more informed judgements. This underlines the need for an iterative planning <u>process</u> rather than a discrete exercise.

A second weakness is that although program objectives and constraints are reviewed in a commodity subsector framework, the prioritized list of research projects focuses almost exclusively on technical research to increase farm-level productivity. There is little attention

devoted to the possibility for technical innovation at other levels in the system, or research needed to help alleviate institutional and policy constraints. This is unfortunate because innovations that lead to productivity gains in the input supply and output marketing will likely increase the probability and extent of adoption of farm-level technology (Reardon et al. 1994). This is partly a reflection of the choice of commodity for the case study. It is common for high-value export commodities that at least some stages in the input delivery and output marketing chain are coordinated by a single organization (e.g., a parastatal) with internal capacity to address technical constraints. Where this is not the case there will be a need to explicitly identify potential constraints upstream or downstream from farm-level producers, and the information and private and public sector participants needed to design technical and related policy and institutional innovations that can alleviate them. One approach to addressing these concerns is to establish a commodity subsector economics program as part of the NARS. This is the route being taken in Mali by the Institut d'Economie Rurale (the national agricultural research institute).

5.3.2. Integrating a Commodity Subsector Perspective in Mali's Research System

The role of the commodity subsector economics program is to help incorporate a food systems perspective into the design of research (Boughton, Staatz and Shaffer, 1994). To help launch and integrate the program with existing research programs, a workshop was organized to bring together technical research program heads, their counterparts in the extension/development organizations, and representatives from the private sector. Commodity working groups were formed to identify major constraints at different stages of each commodity subsector and the role of research and other public and private sector agents in addressing them. The groups used a matrix to guide their discussions (Figure 5). The rows of the matrix represent the different stages of the subsector. The first four columns summarize descriptive information on the current situation and trends, interactions with other subsectors, current policies and their effects, and key actors involved at different stages of the subsector. The next four columns are more analytical in nature, involving the identification of constraints at national and regional level, activities currently underway to address those constraints, and areas where research has a contribution to make. This explicit consideration of different stages by both researchers and development specialists helps to identify complementary constraints upstream and downstream from farms. In the case of irrigated rice, for example, a major concern is to assure effective private sector input delivery and credit as the state liberalizes and withdraws from direct participation in these activities.

Box 5. An Approach to Long-Term Program Design: The Olive Sector in Morocco

Step 1: Review of commodity situation and development objectives. This step has two parts: (a) at the national level, a review of aggregate trends in production and prices, importance of commodity to cash earnings and/or food security for producer and consumer target groups, importance of commodity to foreign exchange earnings/savings, future demand growth, development targets set at inter-ministerial level for production, domestic consumption, export, post harvest/processing losses, and assumptions underlying these targets (e.g., potential sustainable increase in yield for each of these systems); and (b) for each (farm-level) production system its contribution to national production, socioeconomic characteristics and strategies of producers, other economic agents relevant to farm-level production.

Step 2: Analysis of constraints to increases in productivity. Constraints may be technical, institutional or policy in origin, and may occur at farm-level production or post-harvest stages. Constraint trees are used as a brainstorming tool to identify and trace cause-effect relationships between constraints.

Step 3: Review of existing internal and external research results. Domestic research related to identified constraints is classified as follows: results ready for dissemination by extension, results requiring on-farm validation, ongoing research activities scheduled for completion, ongoing research with inadequate resources to achieve meaningful results, research areas with a low probability of success, and questions that are not currently being addressed by research. For external research, the focus is on identifying potential technologies generated by other NARS or international research organizations.

Step 4: Determination of research objectives. For each identified constraint, research activities are identified by agroecological zone and/or by production system. The constraint tree is translated into a research objective (or opportunity) tree. The cause/effect relations between constraints become linkages between research objectives, identifying groups of research objectives that have to be achieved to attain the overall objective. Research opportunities are evaluated for feasibility and potential development contribution. The research strategy to be adopted to realize each opportunity will depend on the stage of technology development.

Step 5: Identification of research areas. Research areas are the next level of disaggregation under the program (e.g., sub-program, project). Each area of research should be comprised of a coherent group of activities, the combined results of which will provide a solution to a problem or exploit an opportunity. This is a crucial task for meaningful priority setting since failure to group related activities runs the risk of some activities not being implemented.

Step 6: Research personnel requirements. Program costs are based on the number of scientist years required, using a standard multiplier for operating funds and support staff. Special equipment is budgeted separately. Personnel requirements are aggregated by discipline and geographical location in order to compare requirements with actual and expected dispositions.

Step 7: Priority setting. Collion and Kissi recommend a scoring model based on economic efficiency criteria, adapted from earlier work by Norton.

Source: Collion and Kissi 1991

A second matrix is used to specify more detailed research objectives and questions that address constraints and information gaps identified earlier (Figure 6). Once detailed questions were adequately specified, the groups identified information that is or may be available and its location, what information needs to be generated by new research, and who the key informants are. The respective roles of the CSE program and other research programs were also defined.

The first phase of implementation will involve an initial subsector appraisal to verify, prioritize and better define the constraints to be addressed in subsequent phases. Specific tasks will include a comprehensive literature review, informal surveys in order to better understand and incorporate the perspectives of different actors in the subsector (especially the private sector), and secondary data analysis (e.g., marketing margins). On the basis of this initial appraisal, a limited number of in-depth studies of constraints identified during the workshop (and/or raised in the course of the initial appraisal) will be formulated in cooperation with other IER programs, the private sector and development organizations. The initial appraisal also enables the identification of participants for the networks of private and public sector agents needed to design and implement solutions to priority problems.

5.3.3. Building Links between Farm-level Production and Agricultural Policy in Senegal

While agricultural sector policies can have an important impact on incentives for technology adoption, how these effects are transmitted through the commodity subsector can rarely be fully anticipated in advance. Thus it is not enough to simply design and implement policy innovations. If policymakers are to have an adequate understanding of whether or not policy innovations are achieving their intended objectives, then policy research needs to become an integral part of agricultural research programs. An example of the application of a food systems perspective to guide research that captures the linkages between policy change and technology adoption is the Bureau d'Analyses Macro-Economiques in Senegal (BAME).

The BAME was established in 1982 as a unit within ISRA (Institut Sénégalais de Recherches Agricoles), reporting to the Director General. The BAME's mission as initially defined was:

- to carry out macro-economic research on food, nutrition and agricultural policies in order to provide guidance to policy makers on economic and institutional constraints on agricultural production and marketing with emphasis on the foodgrain subsector (Bingen and Crawford 1988, 44).

Locating the BAME within ISRA was considered essential to encourage attention to agricultural issues, and to foster a scientific research approach rather than a focus on short-term "quick and dirty" studies. A Consultative Group of high-level government and donor representatives was established for the BAME. This group reviewed the BAME's preliminary research plan, suggested some changes in research priorities, and gave their stamp of approval to the final plan.

Figure 5. Matrix for Identifying Commodity Subsector Constraints and Research Questions

COMMODITY GROUP: _____
COMMODITY SUBSECTOR: _____

STAGE OF THE FOOD SYSTEM	Current situation and trends	Interaction with other commodity subsectors	Current policies and effects	Private and public sector actors	CONSTRAINTS		Actions being undertaken to address constraints	Areas where research is needed
					Nationa l level	Regional trade		
INPUT SUPPLY - seed - livestock feed - chemicals - ag. equipment - credit								
MAJOR FARMING SYSTEMS OR REGIONS	A B C							
MARKETING - assembly - transport - packaging - storage - distribution								
PROCESSING - primary - secondary								
CONSUMPTION - primary products - by-products								

Figure 6. Matrix for Planning Commodity Subsector Research

COMMODITY GROUP: _____
COMMODITY SUBSECTOR: _____

STAGE OF THE FOOD SYSTEM	Research objectives	RESEARCH QUESTIONS		INFORMATION NEEDS		RESEARCH ACTIVITIES		Participants and responsibilities in research implementation
		Specific questions	Private or public sector actors	Available/ sources	Research needed	CSE program	Other programs	
INPUT SUPPLY - seed - livestock feed - chemicals - ag. equipment - credit								
MAJOR FARMING SYSTEMS OR REGIONS	A B C							
MARKETING - assembly - transport - packaging - storage - distribution								
PROCESSING - primary - secondary								
CONSUMPTION - primary products - by-products								

Staffing for the BAME consisted of a Senegalese Director with a doctoral degree in sociology (who was also the Director of the Production Systems Research Department), six Senegalese economists with U.S. master's degrees, and three expatriate economists with Ph.D. degrees. Three U.S. Ph.D. candidates spent 18-24 month periods conducting field research in support of BAME programs.

BAME activities focused on six major research programs: (1) cereals marketing in the Peanut Basin, (2) cereals marketing in the Senegal River Valley, (3) economics of agricultural production, (4) analysis of the food situation, (5) fruit and vegetable marketing, and (6) fish marketing. Examples of research activities carried out under these programs include:

- Price and grain transactions data collection in major rural markets, and field studies of grain assemblers and wholesalers
- Studies of the impact of government regulation on grain trader practices and costs
- Comparative analysis of the official and parallel grain marketing channels, including studies of the costs and throughput of village-level rice mills
- Studies of agricultural credit, and of the fertilizer and peanut seed distribution systems
- Preparation of a country-wide set of detailed crop budgets, which served as the basis for representative regional farm production models, and an aggregate national production and trade model used to examine the impact of the government's cereal self-sufficiency objectives
- Long-term projections of food supply and demand
- A ten-year retrospective study of Senegal's trade in agricultural inputs and outputs

Several activities, especially the analysis of cereals marketing channels, and credit and seed distribution studies, were conducted in close collaboration with regional farming systems research teams. This "micro-macro" linkage improved the flow of information between the field and the center, resulting in a better understanding of farm- and market-level realities on the part of policy analysts, and a better understanding of the current policy issues and priorities on the part of researchers.

Data collected under the cereals marketing studies aroused great interest in government circles, and the procedures developed in those studies were adopted by the Food Security Commissariat's national program for collecting and reporting agricultural prices. The study of fertilizer distribution, because of its timely execution and policy relevance, helped establish the credibility of the BAME as a policy research unit. Its results were used in designing subsequent donor projects, and by the government in revising its agricultural policies. The studies of the food situation helped identify costs and tradeoffs associated with the government's food self-sufficiency policy, and invited presentations of the results were made at numerous seminars with government and donor representatives.

The BAME is also an example of the importance of strategic planning to assure organizational stability. Despite its reputation for valuable agricultural policy analysis studies the BAME was eliminated in 1986, but subsequently restored in 1992. Lack of operational funding to implement studies, lack of training opportunities, and low salaries have contributed to a steady erosion of human capital that have found other opportunities in the private sector or international agricultural research.

5.4. Summary

In general, the kind of process we outline does imply a greater level of investment of research personnel resources in planning agricultural research on a continuing basis than hitherto. This is because strategic agricultural research planning is more than a method for resource allocation - it is a way of building networks of specialists in the private and public sector to identify and realize opportunities for increased productivity in the food system.

Enabling a strategic agricultural research planning process requires three initiatives:

(1) building networks of clients and stakeholders (including researchers) who have direct experience of the constraints affecting, and knowledge of opportunities for innovation and investment in, the different components of the food system to which the program's clients are linked;

(2) providing effective linkages between these networks and agricultural sector investment planning and policy formulation at ministry and inter-ministerial level;

(3) strengthening marketing and policy analysis capacity within NARS in support of (1) and (2). Despite sweeping changes in the incentives for technology adoption following market liberalization and related structural adjustment measures (e.g., currency devaluation) in many African economies, this capacity remains either weak or unmobilized (e.g., because it is located in universities or planning units without effective linkages to national research institutes) in the majority of NARS.

6. STRATEGIC RESEARCH PLANNING AT THE REGIONAL LEVEL

The fundamental concepts for strategic planning at the regional level are the same as those at the national level: working from a vision of agricultural transformation to strategies and then to tactics, guided by a food systems perspective. Strategic research planning at the regional level involves consideration of how to increase the capacity of individual NARS to plan and implement research, and how to enhance the cost effectiveness of total research investment in a given commodity by a region's NARS, through capturing economies of scale and gains from specialization. Regional organizations can also help NARS by reducing the transactions costs of negotiations concerned with the regulatory environment for technology development and transfer between countries. However, the achievement of potential gains depends critically on the extent to which coalitions for collective action can be built at a political level. We first examine the nature of the potential gains in more detail, and then the political considerations.

6.1. Potential Gains from the Regionalization of Technology Development and Transfer Activities

A key advantage of a regional approach to technology development and transfer is enhanced cost-effectiveness in the development and delivery of improved agricultural techniques. This enhancement is usually the result of one of three types of actions: direct purchase (leasing, copying, borrowing) of improved techniques from other countries and regions, exchange of information among scientists and outreach specialists within the region (research consultation), and coordinated efforts to solve common problems.

Direct transfer of applicable (or adaptable) techniques from other countries or regions eliminates the need to develop such techniques within each country. Examples of successful past transfers include the adoption of the Zimbabwean maize SR52 by other countries in southern Africa; importation of hammermills by West African countries; transfer of improved, streak-resistant maize to the CMDT region of Mali; and movement of matoke banana from Uganda to neighboring areas in Kenya.

Research consultation involves exchanging information and results with other researchers and clients, usually in a regional meeting or through a regional network. This exchange helps identify known results, available techniques, and areas of further concern, and may help scientists get ideas about how to solve particular problems. Nonetheless, the actual work of creating knowledge, solving problems, and transferring techniques is undertaken by each national organization as it deems appropriate. The advantages of working in a regional consultation mode include:

- Greater availability of a critical mass of scientists and knowledge at the regional level.
- Better genotype x environment and technology x environment trials.
- Less redundancy of research, testing, and screening activities.

- Improved distribution of public research goods, particularly new knowledge.

Collaborative research takes the consultation mode another step, and involves collective pursuit of new knowledge or solutions to problems. Investigations and experiments are carried out jointly in two or more countries. The advantages of this mode include:

- Improvement and standardization of new research methods enhance reliability, and facilitate comparison and borrowing of research results.

- Standardized testing and certification methods reduce the costs of transferring inputs and outputs across national borders.

- Regionalization ameliorates the impact of political instability on technical knowledge and research results.

- Greater scope for increasing agricultural productivity in Africa's diverse agro-environments.

In the policy context, regional organizations accountable to NARS and with political support from groups such as the relevant Conference of Ministers of Agriculture may be the only type of public research organization that can promote needed policy or regulatory changes at the regional level. For example, trade policy liberalization, standardization of phytosanitary restrictions on cross-border trade of seeds and planting stock, and harmonization of legislation and enforcement for protecting intellectual property rights are inherently regional actions that will be unsuccessful if undertaken unilaterally.

6.2. The Political Economy of Regional Activities

From a political economy perspective, the case for regionalization is one that recognizes the primacy of national systems in responding to the needs and opportunities of their citizens. The greater the perceived benefits of regionalization to individual NARS, the greater will be the political support for regional action within those NARS. The vision for strategic planning at the regional level is to help NARS achieve their goals. At the same time, regional organizations and activities should not be a replacement for organizations or activities that can be undertaken more effectively at the national level. Thus, the strategy for regional organizations is to look for those areas in which they can make a unique contribution to achieving national objectives.

Some regional organizations have a mandate for research and development activities (IARCs, CRSPs), and may need to find ways to disseminate their results (especially CRSPs, which do not have a mandate for transfer). In other cases, the organizations may play the role of coordinator (SACCAR, ASARECA). This role may include some research, but will also help link researcher with researcher, or may help link researchers and extension agents or other participants in technology transfer.

Regional networks are groups of individuals employed in national organizations who link together for a common purpose. The purpose of TDT networks is usually information exchange (research consultation), or joint efforts to solve a common problem using a coordinated agenda (research collaboration). In many cases, these networks are coordinated by an IARC, CRSP, donor, or other organization with a regional mandate. In some cases, these networks include representatives of the private sector.

For illustrative purposes, a list of six questions could be used to help define the role of the regional organization.

- With which national priorities is the regional organization's mandate compatible?
- Can regional or global economies be realized from working in these priority areas?
- How can regional activities best help the national programs and stakeholders?
- What related activities are other national and regional organizations planning?
- What is the best organization to carry out the regional activities?
- What is the best organizational form in which to conduct the activity?

Certainly the first question is most easily answered if the NARS have undertaken their own strategic planning exercises--but if they have not, the regional organization must still grapple with this issue. The second and third questions are related, oriented towards defining what is unique about attacking a problem from the regional perspective. The last three questions are more tactical in nature. They help to define the limitations and delimitations of any proposed action by the regional organization in question.

From the perspective of ensuring adequate political support for regional activities, the following guidelines are useful for determining if the proposed action is appropriate at the regional level (Blase et al. 1994):

- The action is requested by one or more NARS or constituents for assistance with a well-defined problem or opportunity.
- The support is part of the regional mandate endorsed by the regional organization, or its oversight committee.
- The NARS or their parent organizations commit to the national actions necessary to achieve the intended reform.
- The action taken by the regional organization is complementary to the interests of other national systems within the region.

- The action taken by the NARS is complementary to the other national systems within the region.

- The regional organization has a comparative advantage in providing the requested support (it is more cost-effective to deliver at the regional rather than national level?).

Finally, it is extremely important to note that strategic planning in the regional context, as in the national context, is an ongoing process. Changes in national priorities, reallocation of national research resources, actions taken by other regional organizations, growth and strengthening of the organization in question, in addition to the socio-economic and agroecological issues external to the regional organization, all affect the options of the organization in promoting economic growth. Thus, it is important to have a continuing dialogue on the potential effectiveness of strategic and tactical options available to the organization.

7. CONCLUSIONS

The contribution expected from agricultural research is multi-faceted, including improvements in **real incomes** for consumers and producers through increased productivity in food, beverage and fiber commodity systems, **alleviation of poverty and food insecurity** for the most vulnerable groups in society, **enhanced sustainability** of the natural resource base, and **agricultural transformation** manifested by strengthened linkages with and enhanced resource flows (e.g., foreign exchange) to other sectors of the economy. The impact of agricultural research investments on these objectives will depend on the fit between technology development and farm-level needs, and complementary investment and innovation in institutions, organizations, technology and policy in the off-farm components of the food and fiber system.

Agricultural sector needs, capacities, and linkages are continually evolving. This is particularly evident now, when structural adjustment policies and political change are rapidly transforming user demands for new technology and the economic environment in which it must perform across Africa. The challenge is how to design agricultural research as a strategic, dynamic input to promote broad-based economic growth, structural transformation, and food security in the market-driven, but fragile, economies of Africa.

We maintain that a process for designing agricultural research as a strategic input will have three distinctive characteristics:

(1) A **vision** that recognizes the link between research and agricultural transformation. The transformation from low-income agricultural economies involves increasing specialization and productivity in farming through the acquisition of science-based inputs from the rest of the economy in exchange for farm products. But this transformation will only occur if the agricultural sector and the broader economy are effective in delivering the required inputs (including food and other consumer goods) to the farming sector, and providing labor markets and off-farm enterprises to employ labor not required for farming in more productive activities. This implies the need for a **strategy** that ensures complementarity between technological change and improvements in institutions and policies necessary to foster greater integration and exchange within the economy, and for **tactics,** the development of feasible action plans, that bring together research clients and stakeholders.

(2) Strategic program planning must be a continuing **process** of problem solving and allocation of resources, not a one-shot exercise. The uncertainty inherent in technology development for rapidly changing food systems requires a planning process that is able to adjust priorities and activities in response to new opportunities or changed conditions.

(3) Strategic research program planning must go beyond consultation with farmer clients of research. Improving food security and food system performance requires increased productivity throughout the food system, not just at the farm level. This requires the formation of broader **networks of public and private sector clients and stakeholders** including merchants, processors, input suppliers and consumers who must make the

transformation process work. The effective participation of this expanded set of research clients in the planning process is a key to making the selection of research priorities more market-responsive. Beyond this, the networks constitute a potentially powerful coalition that can support and monitor the implementation of research programs themselves. Just as important, they can identify and facilitate the implementation of institutional and policy innovations critical for adoption of technology.

Strategic Agricultural Research Program Planning (SARPP) can be thought of as a sequence of questions whose answers will help to define a vision, strategy and tactics that will lead to a greater payoff to investments in the research program. These include:

- What are the development goals and objectives for the agricultural sector, commodity subsector (or geographical region or resource) that a research organization or program is concerned with?

- What are the major constraints (in regard to technology, infrastructure, institutions and policy) to the realization of those goals and objectives, and what are the relevant boundaries for analysis of the constraint (regional, national, sub-national)?

- What are the opportunities for technological innovation at farm and/or other stages in the food system? Do the technologies exist or must they be developed, and if they exist at what level (national, regional, international)?

- To what extent are potential technical innovations dependent on or responsive to investments, or policy or institutional innovation in the food system?

- Who are the relevant direct clients (technology users), indirect clients (those other than technology users who gain or lose from adoption) and stakeholders whose participation is necessary to help define and realize the potential contribution of agricultural research?

- How should the NARS choose among (prioritize) alternative opportunities to match activities to available human and financial resources?

The difference between SARPP and conventional approaches to research planning is the use of a food systems perspective to identify the information, analyses and participants needed. A food systems perspective can help inform and better integrate two broad levels of planning.

- At the national level, a food systems perspective can help, through a better understanding of the complementarity between policy, technology and private and public sector investment, to inform decisions concerning the overall level of investment in agricultural research, priorities and resources to be allocated among program areas (commodity programs, farming systems, natural resource management), and the organizational structure for the system.

- At the individual (commodity, farming system or resource) program level, a food system perspective can help guide the development of long-term and more detailed short- to medium-term action plans.

The kind of process we outline implies a greater level of investment of research personnel resources in planning agricultural research on a continuing basis than before. This is because strategic agricultural research planning is more than a method for resource allocation - it is a way of building networks of specialists in the private and public sector to identify and realize opportunities for increased productivity in the food system as they develop.

Enabling a strategic agricultural research planning process requires three initiatives:

(1) Building networks of clients and stakeholders who have direct experience of the constraints, and opportunities for innovation and investment in, different components of the food system;

(2) Providing effective linkages between these networks and agricultural sector investment planning and policy formulation at ministry and inter-ministerial level; and

(3) Strengthening marketing and policy analysis capacity within NARS in support of (1) and (2). This capacity remains either weak or unmobilized (e.g., because it is located in universities or planning units without effective linkages to national research institutes) in the majority of NARS.

APPENDICES

Appendix 1. Mali: The Role of Cotton in the Adoption of Maize Technology

Historically, maize has been a minor part of the research program, but, at a 7% rate of growth in output, maize is Mali's most rapidly growing cereal subsector. The initiative to promote improved maize varieties was taken by the cotton parastatal, the Compagnie Malienne pour le Développement des Textiles (CMDT), in response to chronic food deficits during the mid-1970s. The CMDT promoted a sole maize package consisting of an improved local variety and a set of husbandry practices (time of planting, planting density, fertilization) based on research findings from other West African countries. Additional open-pollinated varieties were released over time.

Adoption of the improved maize package was particularly rapid during 1980-86, when an attractive guaranteed price was offered and extension activities were reinforced by a maize project that included the establishment of a seed multiplication program. The influence of non-research-related investments on technology adoption is clear when the different adoption curves from two agroecologically similar, but with different physical infrastructure, organizations and human capital bases are compared (Figure 3). In the CMDT areas, farmers had a cash surplus from their cotton sales that allowed them to mechanize and develop their farming systems. When authority to buy maize was transferred to rural development agencies, CMDT was easily able to extend the integrated production, input and product marketing services already established for cotton to maize. By contrast, the other rural development agency in southern Mali, Operation Haute Vallee (OHV) did not have an integrated technology development and service program in place, and farming systems are considerably less mechanized than in the cotton areas of CMDT.

Although CMDT's approach was effective in terms of adoption rates, it was not financially sustainable. It required high levels of subsidies from the national grain board and the CMDT itself subsidized village-level collection of maize. Following the removal of guaranteed prices for maize in 1986, maize prices fell and have been subject to considerable variability. Area has continued to expand, but farmers have greatly reduced fertilizer use (credit for maize inputs was also withdrawn), switched back to maize-late millet intercropping, and substituted early maturing varieties better suited to their own food security needs.

The estimated internal rate of return (IRR) to investment in maize research and extension in southern Mali is 135%. The very high rate is attributable to low research costs, since much of the technical package was borrowed from other countries, and the high economic value of maize as an import substitute (Oehmke 1995; Boughton and Henry de Frahan 1994).

Appendix 2. Zambia: Bringing Poor Remote Farmers into the Commercial Market

Hybrid maize was introduced to Zambia in the 1950s. During the colonial era, present-day Zimbabwe was the locus of agricultural research for a Federation that also included Zambia and Malawi. Its spectacularly successful SR52, released in 1960, spread quickly among European farmers along the line-of-rail, and from them to neighboring Zambian farmers.

It is impossible to overstate the importance of maize to Zambian producers and consumers: 70% of total crop area is planted to maize. The need to provide Zambia's politically important urban population (over half of the population lives in cities) with a dependable source of inexpensive, easy-to-prepare food, and a desire to improve small farmer incomes, motivated considerable investment in maize varietal research and complementary institutions/organizations by the government and international agencies beginning in the 1970s.

Following Independence in 1964, the Zambian version of SR52 became contaminated as the result of improper maintenance, and yields declined over time. In the late 1970s the maize team was strengthened by the integration of more university-trained Zambian breeders and the arrival of a Yugoslav breeder who remains with the program today. This group sought to purify SR52 and develop new short-season hybrids that were drought-tolerant, disease-resistant and less management-intensive than SR52. These characteristics made it less risky for all small farmers, and especially those outside the established maize-growing areas of agroecological Region II, to adopt improved maize.

Beginning in the mid-1970s, government policies and organizations created a facilitative environment that drew smallholders into commercial maize production. Pan-territorial and pan-seasonal pricing enforced through an effective parastatal monopoly on maize marketing, substantial fertilizer subsidies, and the countrywide establishment of local depots for sales of inputs and collection of maize were most important. These policies laid the groundwork for the successful introduction of 10 Zambian improved varieties. By the time they were released in the mid-1980s, many small and medium farmers had already adopted fertilizer or SR52 and had increased their maize area for commercial production. Zambia's maize area quadrupled and production tripled between 1974-88.

Adoption of improved maize varieties by small and medium-scale farmers was rapid and extensive (Figure 4). By 1991-92, almost 60% of total small/medium maize area was planted to improved varieties. The rates differed dramatically between regions, reflecting both less suitable conditions for maize production in Regions I and III and the less reliable input and product marketing services farther away from the line-of-rail. Adoption of improved technology is impressive by any standard: in Eastern and Southern Africa (excluding South Africa), only Zimbabwe and Kenya have higher adoption rates. Malawi is agroecologically similar but has never had more than 20% of maize area sown to improved varieties.

The impact of improved technology and the complementary marketing policies was to shift maize production from large to small farmers, and away from the areas of traditional comparative advantage near the line-of-rail to the more remote areas of the country. The costs

of marketing subsidies to effect this shift were uneconomic, however, and in the end unsustainable. When the costs of marketing programs were included in the economic rate of return analysis the average rate of return (ARR) for the 1978-91 period was negative. Extending the analysis period to 2001 resulted in a favorable ARR of 42-49%, under the assumption that the government's marketing costs would decline steeply following the liberalization of maize marketing beginning in the 1992-93 season (Oehmke 1995; Howard 1994).

Appendix 3. Rehabilitation of the Research System and the Oilseeds Subsector in Uganda

Uganda's agricultural research system was severely disrupted by the breakup of the East African Community and arbitrary macroeconomic policies of the 1970s, compounded by the war and civil unrest in the early 1980s. In 1986 USAID began investments aimed at rehabilitating the physical infrastructure at several research stations and strengthening human capital for food crop research and university teaching. The maize program was reinstituted in 1987, and the first new variety, Longe 1, was released in September 1991. The sunflower program was launched in 1988 with varietal trials of imported hybrids, and the Sunfola variety was released to farmers in 1991. The soybean research program was revitalized in 1988 with a multi-locational screening program, and ICAL-131 was released in 1991. These are the first variety releases in Uganda in over 20 years.

Prior to 1972 there was a well-established privately owned edible oil industry that focused primarily on cottonseed. Uganda was self-sufficient in edible oils, and exported substantial quantities of liquid oils and hydrogenated solid fats to Kenya and Tanzania. Amin's 1972 expulsion of Asians who owned the national crushing capacity, and the subsequent nationalization of these industrial assets led to the demise of the edible oil industry. Uganda now imports over 80% of its oil and fat needs. As a result, the government of Uganda is keenly interested in increasing domestic production and processing of edible oilseeds.

While a recent study showed that national processing capacity is sufficient to meet projected national consumption needs up to the year 2000, serious institutional and coordination problems impede the achievement of self-sufficiency. The most serious problem is lack of raw materials. This is partly because returns to farm labor in the production of some oilseeds are below the rural market wage rate. Hybrid sunflower offers more than double the yield of open-pollinated varieties like Sunfola, and could potentially increase gross margins to growers, but there are serious doubts about the ability of the Seed Scheme to multiply hybrid seed. Seed for any high oil content sunflower varieties is not readily available, so farmers plant retained seed that is genetically mixed due to cross pollination. In addition, the lack of grading and quality differentiation creates inadequate incentives for farmers to produce sunflower with high oil content. The low oil content sunflower that is produced constrains processor profits. Donors have launched some small seed multiplication projects in response to the problem, but the sustainability of these efforts is open to question.

Soybean production is constrained by the availability of rhizobia to facilitate nodulation and nitrogen fixation. Use of rhizobium inoculant is expected to increase both soybean yields and soil fertility. A USAID-supported project identified a suitable strain of indigenous rhizobium for Uganda and helped establish a rhizobium production facility at Makerere University, but adoption has been limited so far because farmers do not understand how to use the inoculant, and extension staff have not received adequate training. A second constraint is the lack of distribution mechanisms to ensure the viability of inoculant, and that it arrives on time. Inoculant is inexpensive, but must be protected from extreme temperatures and mixed with the

seed just prior to planting (Oehmke and Crawford 1993; Laker-Ojok 1994a, 1994c; Oehmke 1995).

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