Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research

Volume I: Diagnosing Agricultural Research System Constraints

Proceedings of the ISNAR/Rutgers Agricultural Techn
Workshop, 5-8 July 1988, Rutgers University, N

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International Service for National Agricultura

The International Service for National Agricultural Research (ISNAR) began operating at its headquarters in The Hague, Netherlands, on September 1, 1980. It was established by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force, for the purpose of assisting governments of developing countries to strengthen their agricultural research. It is a non-profit autonomous agency, international in character, and non-political in management, staffing, and operations.

Of the thirteen centers in the CGIAR network, ISNAR is the only one that focuses primarily on national agricultural research issues. It provides advice to governments, upon request, on research policy, organization, and management issues, thus complementing the activities of other assistance agencies.

ISNAR has active advisory service, research, and training programs.

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Proceedings of the ISNAR/Rutgers Agricultural Technology Management Workshop, 6-8 July 1988, at Rutgers University, New Jersey, USA

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Volume I:
Diagnosing Agricultural Research Systems Constraints

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Preface

The International Service for National Agricultural Research (ISNAR) and Rutgers (the State University of New Jersey) organized a workshop on the methods for assessing research impact and for diagnosing research systems constraints. This workshop was held in July 1988 at New Brunswick, New Jersey, USA. It was financed by USAID, IICA, ISNAR, Rutgers University, and the Rockefeller Foundation.

The purpose of the workshop was to provide a forum for discussing the methods of assessing the impact of research and diagnosing constraints on research systems with the goal of developing a consensus on the methodology for both assessment and diagnosis.

A call for papers for the workshop yielded over 50 submissions, of which 23 were chosen to be included. A peer panel of seven professionals — Ralph Cummings (AID), Howard Elliott (ISNAR), Robert Evenson (Yale University), Reed Hertford (Rutgers), Carl Pray (Rutgers), Margaret Sarles (Rutgers), and Eduardo Trigo (IICA) — selected the papers. These papers dealt with original research carried out by their authors. Most papers had neither been widely disseminated nor previously discussed.

Twenty-four authors participated in the workshop, including experts from donor organizations, international agricultural research centers, government agricultural agencies, and university programs in agriculture and economics. These individuals are recognized leaders in the development of the methodologies that were presented. In addition, representatives of NARS from Asia, Latin America, and Africa attended the workshop (sponsored by IICA, ISNAR, and AID) in order to provide feedback on the methodologies under discussion and to learn new analytic skills.

Dr. Reed Hertford, Director of the International Agricultural and Food Program (IAFP) at Rutgers University, was secretary for the workshop. IAFP Staff Members, Ms. Sue Randall, Ms. Marilyn Kluberspies, and Ms. Carrie Foushee, provided administrative support. Dr. Howard Elliott, Deputy Director General of Research and Training at ISNAR, co-hosted the workshop and provided logistic support. Both Dr. Hertford and Dr. Elliott guided the overall development of the workshop.

The workshop was organized around two groups, one that focused on diagnosing research systems constraints and the other on assessing the impact of agricultural research. Volume I of this report includes the papers on diagnosing systems constraints, and Volume II includes those on assessing the impact of agricultural research. Most of the papers included in this volume have been revised by their authors — at the editor's request — since being presented at the workshop in 1988. The editor thanks the authors for their contributions and Monique Hand and Kathleen Sheridan for their assistance in preparing this volume. All views expressed in this volume are the responsibility of the respective author(s).

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DIAGNOSING RESEARCH SYSTEM CONSTRAINTS

Ruben G. Echeverría and Howard Elliott

Abstract

This paper defines a generic agricultural research system and highlights some of the methodologies for diagnosing the research system constraints described in the papers included in this volume. An agricultural technology system is formed by public organizations (such as research institutes and universities) and private-sector organizations (such as input companies, foundations, and farmers' associations). The main methodologies proposed in this volume to diagnose research system constraints are agricultural technology management (ATM) described by Cummings; the ISNAR-Rutgers agricultural technology management systems (ATMS) approach; the International Program for Agricultural Knowledge Systems (INTERPAKS) from the University of Illinois; the systematic constraints analysis process (SCAP) from the University of Hawaii; and diverse approaches focusing on special cases such as sub-Saharan Africa, small developing countries, agroforestry institutes, private-sector foundations, and postharvest fishery research projects.

The objective of this paper is to define a generic agricultural research system and discuss some of the methodologies used to diagnose research system constraints. The paper highlights the main issues in diagnosing constraints to agricultural research systems that are included in the papers that form this volume.

Agricultural research systems face multiple constraints. The first step towards releasing some of them is a clear definition of what an agricultural research system is. We address this issue in the first section of the paper.

Three critical areas can be defined when examining a research system: policy, organization, and management. An effective diagnosis involves analyzing these areas in order to identify principal constraints and how to

release them. The second section of this paper deals with the methodologies utilized to carry out this diagnosis.

A National Agricultural Research System

In a restricted sense, the term "national agricultural research system" (NARS) is often used as a synonym to "public research institute." In a broader sense, the concept of a NARS includes many organizations, public and private, that are involved in generating various forms of agricultural technology (Table 1).

Table 1. A National Agricultural Research System

Sector	Organization
Public	• National (or provincial) research institute or council • Research division of a ministry • University and technical schools • National or regional institutes specialized by product • Other public organizations • International research centers
Private	• Input companies, local and multinational • Processing companies • Large farms and plantations • Consulting firms • Cooperatives and associations • Commodity groups • Foundations

Examples of other public organizations that may conduct agricultural research are the Academy of Sciences and development projects conducted by government agencies, usually with the participation of international agencies and foreign universities. Since a system is defined by its objectives, such organizations may be included as part of the NARS or as part of its environment, depending on the objective being sought.

There are also other public organizations that do not conduct agricultural research but affect the input as well as the output of research. These include the economic, development, and agricultural policy units of ministries, the international development community (CGIAR centers, FAO, World Bank), and donors (World Bank, USAID, regional development banks). All these may also be elements of a national agricultural research system. For there

to be a system, there must be linkages among these various components and a common set of goals.

ISNAR (1987) has identified three essential components of a research system: (1) a coherent research policy designed to meet national development goals, (2) efficient organization, and (3) effective management. These three components are interrelated and mutually reinforcing. A deficiency in any one of them affects the capacity of the others and inhibits the system's ability to develop to its fullest potential. They are, thus, the critical points of intervention in a system-building strategy, and the focus of ISNAR's work (Table 2).

Table 2. Critical Factors of an Agricultural Research System

Areas	Factors
Policy	• Interactions between national development policy and agricultural research policy • Formulation of agricultural research policy: priority setting and planning
Structure and Organization	• Structure and organization of research systems • Linkages between NARS and policymakers • Linkages between NARS, technology transfer, and users • Linkages between NARS and external sources of knowledge
Management	• Program formulation and budgeting • Monitoring and evaluation • Information management • Development and management of human and physical resources • Acquisition and management of financial resources

These critical factors determine the effectiveness and efficiency of a NARS and are an essential part of the framework to diagnose system constraints.

Methodology for Diagnosing System Constraints

Several approaches and methodologies have been proposed to diagnose research system constraints. These include ISNAR's framework for NARS reviews, ATMS, INTERPAKS, and others. We will briefly review these concepts in this section.

ISNAR

ISNAR's framework for NARS reviews is the result of a synthesis of ISNAR's experience in reviewing more than 40 countries in the developing world. These reviews identify system constraints and priority issues for change, outline a range of options, and recommend an appropriate plan of action. A formalized methodology (Dagg and Eyzaguirre 1989) uses a systems approach to evaluate essential organizational and management processes within the NARS, as well as the functions among NARS components. This is done in terms of the scope, coherence, and complementarity of those processes.

When focusing on the *scope* of a system, ISNAR's methodology evaluates the goals of the system in relation to the demand for research, the relevance of the research goals, the actual or planned capacity of the system, and the available and projected level of resources. The *coherence* of an agricultural research system is defined as the degree to which the goals of the system are understood and implemented at the various levels of the NARS. The analysis of *complementarities* includes the degree of complementarity between the financial, human, and physical resources and the research program. It also focuses on the relationships between the planning and priority-setting process and the programs and linkages of the system.

Agricultural Technology Management (ATM)

According to Cummings, the ATM methodology reveals the relationships between new and existing institutions and new and existing technologies. He argues that, instead of realizing that the development of improved technology involves different agents in an interactive process, previous writers have divided the concept of ATM into sections that are provinces of different disciplines. The agents involved in this process are national research systems, public extension systems, universities, farmers, private companies, and government policy-making bodies.

Given the fact that when planning an ATM system, different approaches are needed for different situations, the key issue becomes the identification of principles that characterize successful ATM systems. When diagnosing ATM system constraints, Cummings identifies nine key activities:

- developing manpower — identifying and developing the necessary professional skills to implement a particular research program;

- defining the environment — establishing clear goals for initiating research in the context of the nation's state of development, goals, commitment to agriculture, and the priorities set for the sector;

- setting goals and objectives — as a first step in establishing priorities among commodities, regions, and program components;

- defining the technology agenda — where priorities are set (taking into consideration the most appropriate scientific perspectives and the value to society of the potential new knowledge);

- making the technology agenda work — creating the conditions to enable the different groups conducting research and extension to contribute to agreed-upon goals (which could be achieved by an active public sector providing substantive leadership, by funding only research that conforms to an agreed-upon agenda, or by implementing research and extension directly);

- generating, assessing, and diffusing technology — three connected functions with the final outcome of implementing a research agenda (the generation of technology through research is achieved at the national and the international level by public or private institutions, or some combination of both; assessing technology involves monitoring and evaluating research results; finally, the potential benefits generated by research will clearly not be realized until improved technology is transferred and adopted by farmers);

- promoting adequate continuous stable support — ensuring a high economic payoff as new technology is generated, transferred, and adopted (a crucial point here, as Cummings points out, is that an ATM system must develop a constituency among users in order to generate and maintain support through time.)

Agricultural Technology Management System (ATMS)

An ATMS consists of five principal components (Elliott):

1. the technology sector, including generation, transfer, and users;

2. the politico-bureaucratic structure, composed of government representatives and policymakers;

3. the external sector, composed of donors, international technology-generating institutions, and multinational companies;

4. the underlying structural conditions (including world markets) and the resource base and its distribution within the country;

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5. the policy environment, including the laws, regulations, and practices that influence all components of the technology sector.

The ATMS framework involves three levels of analysis: system, institutional, and commodity level. The system-level analysis describes the system and its evolution, focusing on structural constraints and the policy environment. It includes three types of analysis: functional, event, and policy.

The institutional analysis focuses on the principal organizations that generate agricultural technology in the system and the management of human resources. Key functions analyzed are priority setting, program formulation, and generation and management of financial support.

The commodity analysis assesses the impact of technology-management activities related to specific commodities. This is carried out by case studies using an "intervention opportunity matrix."

The objective of the three-level analysis is to see whether hypotheses about system-level weaknesses are verified at the institute and commodity levels and to identify where interventions are best made.

International Program for Agricultural Knowledge Systems (INTERPAKS)

The INTERPAKS of the University of Illinois has developed a framework for diagnosing constraints in agricultural technology systems that includes three parts: an a priori system macro-model, a set of methodological tools, and an analysis based on flow-system models.

According to Swanson, Sands, and Peterson, the macro-model consists of four subsystems: government policy vis-a-vis the technology system, technology development, technology transfer, and technology utilization. From this macro-model, a set of critical factors and related indicators is constructed to be used as tools in the analysis of technology systems. These factors and indicators are summarized in Table 3.

The second part of the methodology developed by INTERPAKS is a flow-system analysis that maps the institutions and functional linkages making up the technology-development and -transfer system to determine how new technology is expected to flow through to farmers.

Systematic Constraint Analysis Process (SCAP)

Izumi defines SCAP as a process of planning based on systematic analysis of the constraints for the development of a sector, subsector, or program, and

Table 3. Critical Factors and Indicators of the INTERPAKS Framework Used to Diagnose Constraints to Agricultural Technology Systems

Critical factor	Indicator
Public Policy	
Government's financial commitment to agriculture	• percent of total government budget devoted to agriculture for a given year • annual average rate (percent) of total government budget devoted to agriculture over a specific period
Public investment in research and extension	• percent of AGDP spent on research • expenditure on research as a percent of investment in extension • percent of AGDP spent on extension
Availability and utilization of agricultural credit	• percent of short-term production credit from institutional sources going to the agricultural sector • utilization of credit by farm size category
Pricing policy	• gap between domestic (farmgate) and world market prices • ratio of farmgate price of staple food grain crop to the price of the same amount of fertilizer
Technology Development	
Access to external knowledge and technology	• index number of access level
Human resources for agricultural research	• ratio of scientists to technicians • number and percent of scientific personnel at different levels of training • trend in number and quality of personnel over time
Resource allocation to research salaries and programs	• percent of budget allocated to research programs and operations, salaries, and capital investments
Resource allocation to commodities	• financial investment in research by commodity program or crop • index value of research personnel or activity in each commodity compared to each commodity's contribution to AGDP in percent
Technology Transfer	
Access to and availability of internal technology	• nature and frequency of interaction between research and extension personnel
Personnel administration and supervision	• criteria for personnel evaluation and supervision • comparative analysis of salaries and benefits for extension personnel compared with similar groups in other institutions

Table 3. (continued)

Critical factor	Indicator
Time allotted to technology transfer	• amount of time extension staff spend on extension and nonextension duties
Resource allocation between extension salaries and programs	• comparison over time between personnel salaries and program costs
Technology dissemination	• ratio of extension agents to farm households • average number of annual farm visits, annual group meetings, and of resul. demonstrations per agent per year • percent of farmers or households who have direct contact with extension • capacity to produce mass-media outputs and teaching materials • percent of households obtaining information from radio and the number of minutes per week that information is broadcast to farmers
Personnel resources for extension	• ratio of agents to farm households • number of subject-matter specialists as percent of total professional staff • staff qualification by position and years of training
Technology Utilization	
Technology adoption	• percent of area and of farmers using a new technology
	• Access to technology • average distance between farm household, and input supply points
Availability of technology	• supply of physical inputs over time • change in input supply or sales over time • degree of farmer knowledge about recommended practices

the setting of priorities for actions necessary to overcome them. This methodology has been used successfully in planning, funding, coordinating, and managing agricultural research and development projects in the state of Hawaii, the American-Pacific Islands, and Jordan.

SCAP involves the creation of a multidisciplinary task force of researchers, extensionists, and others with the objective of analyzing constraints and preparing a plan of action. This plan is then circulated to a wider audience (public officials, clientele, agribusiness representatives, etc.) to reach a consensus on the priorities and actions to be taken. SCAP claims the advantage of being a pragmatic approach that allows priorities to be reached by consensus based on the planning task force's knowledge, experience, and

expert judgment. Its procedures are described as easy to understand and it addresses on-farm and off-farm factors affecting agricultural production.

Special Cases

Several other approaches to diagnosing specific agricultural research system constraints were presented in the workshop. Examples of these cases form the second part of this volume and include methods for diagnosing research system constraints in sub-Saharan Africa, small research systems, agroforestry institutes, private-sector organizations, and postharvest fishery projects.

Dommen highlights the difficulty of using traditional methodologies for diagnosing research constraints in *sub-Saharan Africa*. He argues that agricultural research has had limited impact in the region because scientists have failed to conceptualize the mixed cropping systems of sub-Saharan Africa's low-resource agriculture. Dommen proposes to consider conservation of resources as an output similar to annual crop outputs. The starting point of this proposal is to consider production functions of farmers at a different level of management, enabling agronomic research to focus on improving farmers' yields (total output of a mix of crops) instead of improving potential crop yields at experiment stations. The focus of the proposed methodology for diagnosing research constraints should be to improve farmers' packages of methods and inputs. This means concentrating more on less-advanced farmers or less-advantaged regions and less on the most advanced farmers, as commodity-specific research tends to do.

Another special case of diagnosing research system constraints concerns the *small developing countries*. Researchers in these countries usually face the same range of demands as their colleagues in larger countries, but they have fewer resources available to meet these demands. Gilbert et al. consider this issue in general and provide an example from The Gambia, while Anderson et al. examine how to set agricultural research priorities in a small country (Papua New Guinea).

Scherr examines institutional factors required for effective *agroforestry research* and develops guidelines for rapid diagnosis of constraints in different types of agroforestry research institutions. Numerous institutional factors have constrained agroforestry research: interinstitutional conflicts, lack of a development perspective in setting research goals, an inadequate scientific perspective for evaluating integrated land-use systems, a lack of focus on farmers' realities, and a conservative institutional environment.

Scherr proposes to evaluate institutions based on five elements: political coordination of the research agenda, development focus in research, multi-

disciplinary coordination, an on-farm focus for research, and the environment for research innovation.

Agricultural research has been traditionally examined from a public-sector perspective, without considering the role and impact of the private sector. This has obvious implications when diagnosing agricultural research system constraints. In the few studies where private research is included, it is usually done in a conventional way, i.e., by considering input companies only. Other institutional models such as research conducted, or funded, by farmers' organizations and foundations are normally not considered.

Sarles reports on USAID's experience with *private research foundations* in Latin America and the Caribbean. Examples of these institutions are the agricultural research foundations of Honduras, Jamaica, the Dominican Republic, Ecuador, and Peru, as well as those proposed for Guatemala and El Salvador. Sarles' explanation of USAID's decision to move from the traditional funding of public research in the region is based on (1) the agency's emphasis on support for private-sector alternatives, and (2) institutional fatigue, caused by continuous funding of the same public institutes year after year.

Morrissey and Pollnac examine the numerous constraints involved in planning research projects in *postharvest fishery technology*. These constraints are in the areas of resources, harvesting, transportation, processing, and marketing in the fisheries sector.

Two other issues associated with the diagnosis of agricultural research system constraints are also included on this volume: (1) a specific method to relate new technology and development and (2) strategic planning in international research organizations.

Doherty proposes a *social network methodology* to analyze social structure and development using relational matrices. His paper focus on some of the matrix-based procedures used in network analysis and interprets them in terms of culture theory and social structure.

Ozgediz discusses the importance of conceptual and process issues related to *strategic planning* in international agricultural research organizations. He proposes a framework that integrates planning, evaluation, and control. This framework consists of strategic, operational, monitoring, evaluation, and control concerns that can be applied to multi-institute, institute, and program activities.

Conclusions

Technology generation and diffusion is a continuous process in which many institutions, organizations, and agents have an input, and the relations among them may be changing. An agricultural research system may include many organizations, public and private, local and foreign. It should not be taken as synonymous with a national research institute, and its relations with the broader agricultural technology-management system must be made clear.

Agricultural research systems face multiple constraints, and diagnosing these constraints requires analysis in the three critical areas of policy, organization, and management. Five important considerations are relevant when analyzing an agricultural research system: the system's (1) objectives and performance measures, (2) environment, (3) resources, (4) components and their activities, goals, and performance, and (5) management.

The papers included in this volume can be divided into conceptual, methodological, and special applications. Approaches diagnosing agricultural research system constraints and of managing agricultural technology are relatively new. Operational tools are still being developed. Clearly there is no single methodology that can be applied to diagnose constraints in all agricultural research systems. However, despite this diversity of situations, some principles can be applied:

- There is a need for simplicity in the framework to be utilized.
- The analysis must be cost effective, replicable, and easy to use by managers.
- The analysis must be proactive (description and understanding should lead to action).
- The methodology must be chosen for the particular context (system or institute level).
- The time frame and resources must be made explicit.

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Other references refer to the papers included in this volume.

General Methods

AGRICULTURAL TECHNOLOGY MANAGEMENT: Draft Guidelines

Ralph W. Cummings, Jr.

Abstract

Agricultural technology management involves the interdependent relationships between new and existing institutions and new and existing technologies as they are directed to meet acceptable and feasible responses by individual producers. No single blueprint can be universally applicable in planning an agricultural technology management system. Different approaches are needed for different situations. This does not mean that every situation is unique. It should be possible to identify principles that characterize successful systems by focusing on key concepts that cut across disciplines and departments. Key activities, which are the pressure points in the *strategy* of agricultural technology management can also be identified. This paper provides a framework for (1) evaluating proposed agricultural research and extension projects in low-income countries and (2) identifying the limiting factors that must be dealt with to fit a proposed project more closely to the national goals and resources available in the country concerned.

There are many interesting research problems. Some of them are important.

Richard Bradfield

My personal experience as a member of research review teams and as both a staff member and an administrative officer at institutions subject to external review has led me to the conclusion that such reviews are usually regarded as highly unsatisfactory. A fundamental criticism involves the tendency for review teams to focus on the details of scientific, agronomic, or engineering research methodology rather than on strategic considerations in the design of the institute or station research program.

Vernon Ruttan

Introduction

Improved technology, adapted to the needs and capabilities of farmers, is a necessary condition for agricultural and rural development. Technology alone cannot do the entire job of agricultural development. A range of institutional innovations, supportive policies, and infrastructure investments must occur if agriculture is to develop and the benefits are to be spread widely among the rural population. However, without continuing generation and diffusion of improved technology, few programs will move very far or have lasting effect.

This paper is intended to provide a framework for (1) evaluating proposed agricultural research and extension programs in low-income countries and (2) identifying limiting factors that must be dealt with to fit a proposed project more closely to the national goals and resources available in the country concerned. These draft guidelines have been prepared with an awareness that no single project can be properly evaluated without reference to the socioeconomic, political, scientific, and resource setting in which it is expected to operate and to the existing institutions with which it must work.

Agricultural Technology Management

Agricultural technology management involves the interdependent relationships between *new* and *existing institutions* and *new* and *existing technologies* as they are directed to *meet acceptable and feasible responses* by *individual producers*. It implies the desirability and capability of linking and harmonizing the various functions and interactions in an operational sense. What is meant is internalizing (endogenizing), by some management means, as many of the functions as are necessary to generate, assess, and diffuse the improved technologies that will increase agricultural production and incomes.

Generally, the concept of agricultural technology management has remained disjointed, broken into pieces that are provinces of different disciplines and departments. However, development of improved agricultural technology is a *continuum* that should involve a spectrum of participants in an interactive process. The four principal action agents for technology development — which encompasses the generation, assessment, and diffusion of technology — are (1) national research systems, (2) public extension systems, (3) universities/faculties of agriculture, and (4) farmers and farm households. Also of significance are (5) service institutions, such as seed, fertilizer, and pesticide distributors, veterinary services, credit agencies, and commodity traders and processors, and (6) government policy-making bodies for prices, marketing, roads, etc. Technology development activities may be accom-

plished by private, public, or quasi-private institutions, or some combination of these. Attempts to separate the various components (in time, conceptually, or organizationally) introduce "static" or, worse, disrupt the technology generation-assessment-diffusion process. National agricultural research and extension agencies traditionally have been separate entities (at least operationally) and have lacked effective linking mechanisms. There is limited feedback from the farmer to research, reducing the probability that research efforts address real problems and priority concerns. There is also infrequent interaction between research and extension institutions and government policy-making bodies. Without such feedback and interaction, agricultural development suffers.

No single blueprint, no single formula, can be universally applicable in planning an agricultural technology management system. Different approaches are needed for different situations. This diversity does not mean that every situation is unique. It should be possible to identify principles that characterize successful agricultural technology management systems. Which or what combination of institutional alternatives should be chosen and how they should operate depends on their comparative effectiveness, which may be evaluated by cost-effectiveness or other suitable criteria and by whether or not output and farmers' incomes are increased. Whether these increases are sustainable and the particular settings in which they occur should also be considered in the evaluation process.

The dilemma can be remedied by focusing on key concepts that cut across disciplines and departments. As with most approaches that seek to encompass a system in a holistic manner, the numbers of factors that have to be investigated in agricultural technology management are large indeed. In such situations, F. F. "Frosty" Hill, former vice-president of the Ford Foundation, recommended: "Search out the key log in the jam and attack it first. If the key log is immovable, waste not your efforts thereon but move to the second log. Remember not to dissipate all of your energy on one log in the jam for there are others that also await your attention." A holistic or systems approach tends to suggest so many rabbits to chase that it becomes difficult to catch very many of them. One means of overcoming this problem is to identify what may be Frosty's key logs.

Whether or not it is so defined, a national agricultural technology management system exists in every country. By systematically assessing the activities of the system, reviewing alternative ways that the activities might be implemented, and suggesting means by which the relative feasibility of the alternatives might be evaluated for particular situations, ways of improving the operation of the system can be identified. Key activities — the pressure points in the *strategy* of agricultural technology management — are the following:

- Identifying and Developing Necessary Skills
- Defining the Environment
- Setting Goals and Objectives
- Defining the Technology Agenda
- Making the Technology Agenda Work
- Generating Technology
- Assessing Technology
- Diffusing Technology
- Promoting Adequate Continuous Stable Support

Each activity will be discussed in turn. Illustrative questions will follow each discussion.

Identifying and Developing Necessary Skills

It is difficult, if not impossible, to develop meaningful programs without an adequate base to implement them. A country's success in building an agricultural technology management system and extending it to all its regions depends in large part on its ability to attract and develop a substantial number of professionals/technicians who understand program objectives, who command basic farming skills, who are well grounded in agricultural science and technology, and who are oriented to acting fast. Therefore, a review of agricultural technology management must begin with an examination of the present and projected professional staff. A personnel inventory should be established and a clearly defined program for developing the necessary skills should be projected.

Questions:

What types of skills and levels of training are presently available — in the research agency, in the extension agency, in universities, in other government agencies, and in the private sector? What types of skills and levels of training are needed?

Does the agricultural technology management system attract and retain the "best" scientific and technical talent available? If not, why not? If so, how? What are personnel recruitment procedures? How do the "conditions of

service" compare with other career opportunities for scientists and technicians in the area? What is the promotion and reward system and is it competitive?

How is staff development and training carried out? What procedures and financing are required?

Is the technology management system related to educational institutions in the country? How? If so, what are the effects in terms of quality of research and extension? Are the activities regarding technology generation, assessment, and diffusion contributing to strengthening the training institutions by providing a problem focus? Do research and extension staff in government agencies interact with agricultural faculty and students on a regular basis?

Is the technology management system supplemented by technical collaboration from outside sources, e.g., donors? If so, how is this collaboration coordinated with staff of the national technology management system?

Defining the Environment

The world with which the agricultural technology management system must work must be defined. The rationale for initiating work in proposed problem areas should be clearly set forth in the context of the nation's state of development, its goals, its commitment to the agricultural sector, and its agricultural priorities. These conditions are unique to each country.

Questions:

What is the size of the country in terms of population, gross national product, and land mass? What are the terrain, rainfall, and other important physical characteristics? How extensive are the roads and access to internal and external markets?

What is the budget condition of the country? What is the policy environment in which agriculture must operate? Does the country have a national development plan? If so, how does the technology management system fit within that plan?

What are the levels of literacy and numeracy? How strong is the science and technology orientation of the country and how is it manifested? Are there specific cultural or historic circumstances that condition systems of management? Are there known antagonisms among different elements of the society? How developed is the private sector, how free is it to operate and in what areas?

Setting Goals and Objectives

Government efforts in the past have often centered on individual components such as credit, seed, extension, or even research, often with disappointing production results. Such failures usually stem from remaining weaknesses in the system. Usually the fault for failure has not been the farmer's; it lies in the design or execution of programs, including policy components. Setting goals and objectives to be achieved is the first step toward establishing priorities in the technology agenda among commodities, among regions, and among program components. The process by which goals and objectives are set, the actual specification of objectives, and the means by which progress, or lack of progress, is to be measured are all important. Therefore, a useful statement of goals and objectives should include specifics on the constraints to be addressed; the feasibility of addressing them; the significance of success, if achieved, in dealing with them; and the probable impact of the effort on the people, institutions, and development process of the country.

Farmers, regardless of the size of their holding, generally increase their productivity if they have the incentive to do so, that is, provided *four* requisites are met:

- *An improved farming system.* A combination of materials and practices that is clearly more productive and profitable, with an acceptably low level of risk, than the current one must be available to the farmer.

- *Instruction.* Farmers must be shown, on their own farms or nearby, how to put the practices into use, and they should understand why and under what conditions these practices are better.

- *Supply of inputs.* The inputs required and, if necessary, credit to finance their purchase must be available to farmers when and where they need them, and at reasonable cost.

- *Availability of markets.* The farmer must have access to a nearby market that can absorb increased supplies without excessive price drops; that is, the product prices available to farmers must be right.

If all these conditions are met in any locality, it is likely that a high proportion of farmers will, in time, change. If the combination is incomplete, farmers will hesitate to abandon their traditional ways.

The way that goals and objectives are stated can be of great importance. There is a significant difference between an objective of releasing 10 to 15 improved varieties over 10 years and one of doubling production or doubling

incomes from agriculture in 10 years. The first view, encompassing the traditional roles of research and extension, measures contributions in terms of limited criteria focusing on the first two of the four requisites. Researchers or extension agents can say that they have done their jobs and it is someone else's fault if the technology is not adopted. The second view, which embraces all four of the requisites, accepts that good science is important but not enough, it recognizes that most governments will not support science for science's sake for very long, and it measures the contribution of technology management as part of a total effort. It assumes that government is committed to do what is necessary to achieve the objective of accelerated agricultural development, and it takes responsibility, particularly with a broader view of research, to assist government in achieving that objective.

The time frame for goals and objectives is also important. While some results can be produced which have quick applications, research more often has longer-term payoffs — usually results can not be expected before five to 10 years after research is initiated. Research decisions made now will plot the pattern of the future. In *Creating a Progressive Rural Structure*, Arthur T. Mosher (1969) recounts traveling across the Indo-Gangetic Plain with a friend who asked, "Will this region ever be as productive as Iowa?" Although Mosher had lived and worked in that region of India for many years, he had not asked himself such a question. He states, "I realized that I had been guilty of a common error. Too frequently we ask ourselves only 'what should we do next?' We do not look far enough down the years, visualize what should happen ultimately, then work backward to the present as well as forward from where we are now developing our plans." Therefore, a look to the future, i.e., where the country or the region is likely to be in the year 2000, can provide guidance about what research should be supported now to influence that future.

Questions:

Where does the country want its agricultural sector to be by the year 2000? How does it propose to get there, i.e., what path should be taken? What programs should be initiated now to move to and along that path to the desired objectives?

Defining the Technology Agenda

The technology agenda identifies what the technology management system must do in order to achieve its objectives: it clearly states priorities. The basic task is to select the most appropriate scientific perspective for each problem, then to frame the specific experiments and studies that will give results that might realistically and usefully be put into practice. The technology agenda should focus on providing improved farming systems —

generating technologies. But it should do this in a way that recognizes and, if feasible, provides information to address the other requisites to increased productivity.

In developed countries, continuous interaction among farmers (especially producers' organizations), extension agents, and the researchers' peer review system provide a highly sophisticated and natural framework for the selection of research and extension programs and projects. When these mechanisms are not feasible, other, perhaps more formal, means to assure the development of an effective program are needed. Whatever the mechanism, specific research and extension projects can be assigned priorities regarding the following:

- The possibilities of advancing knowledge or technology if resources are allocated to a particular commodity, problem, or discipline.
- The value to society of the new knowledge or technology if the research effort is successful.

There is one major complicating factor in this process which, in part, must also be addressed in the next two sections: What is the minimum size needed in a research organization for it to provide effective results? If a country is too small to support this minimum size, should it forego research, spread its resources over the whole spectrum, or concentrate on a few commodities, problems, or disciplines? On what basis can a country make this decision? One solution to this problem is to harmonize research activities with other countries or institutions located outside the country.

Questions:

By what process are constraints identified? By what process are research priorities established? Are the research priorities relevant to the problems of the country? If so, how is this established? Who does the analysis? Who decides which programs and projects are to be supported? Do farmers and extension workers participate in identifying constraints to increased production and in planning the research agenda? What information, collected and analyzed in what manner, is necessary to establish priorities to plan, implement, and evaluate the system? Do both social scientists and biological scientists participate in and contribute to the final results?

Who sets the technology agenda — administrators, bureaucrats, scientists, politicians, or someone else?

Are the problems to be studied those that require research for their resolution? Is the proposed research technically feasible, economically profitable,

socially acceptable, and environmentally sound? Are research institutions available to do the research? Will the research contribute to strengthening national research institutions?

Are the topics relevant to the high-priority problems of agriculture in the country? Are there mechanisms in place to utilize the results of the research generated, including use by the private sector? Is there a likelihood that significant numbers of needy people will benefit, within a reasonable time period, from the application of the research results?

Making the Technology Agenda Work

The next step is to ensure that the system actually does what it says it intends to do. Variables are *endogenous* if they can be influenced by agricultural technology management or *exogenous* if they are outside control and have to be lived with. Exogenous variables that define the nature and scope of an agricultural technology management system include country scale, physical characteristics, infrastructure, financial resources (including the terms of support) of the public sector, politics/politicization of the system, management tradition, policies, professionalism, the orientation of science and technology, educational level, agricultural technology base, existence and accessibility of international networks, and extent and composition of the private sector. The more narrowly defined the system is, the more variables are outside control. Agricultural technology management should attempt to endogenize (i.e., attempt to gain influence over) as many of the exogenous variables as possible.

Often several different groups in a country are carrying out or could carry out research and extension programs. Technology management systems have a range of options available to enforce the technology agenda, that is, to see that the different groups are contributing to agreed-upon goals in a coordinated or complementary manner. These means are not mutually exclusive. The first of the options is substantive leadership — exercising sheer intellectual power of persuasion by identifying and promoting a reasonable, challenging program. National commodity research and development schemes and periodic provincial, state, or regional consultations are means of exercising this leadership. The second option is to exercise the power of the purse — to fund only research that conforms to an agreed-upon agenda. The ability to successfully exercise this option depends on controlling, either directly through appropriation or indirectly through power of approval, a large portion of research and extension funding in the country. National councils are a usual means of combining the first two options. A third option is to implement research and extension directly. Direct implementation, which embraces both the first two options, is the surest way to enforce the agenda but also may exclude potential researchers, particularly

university faculty and the private sector, who might contribute positively to the process. Whichever option or options are used, the challenge is to encourage individual initiative, while at the same time influencing initiatives toward contributing to national development goals.

Questions:

How is research and extension apportioned among participants; what portion of research and extension is done under the ministry of agriculture? How are the technology priorities monitored? Are the different research institutions in the country, including universities and the private sector, linked and are their activities encouraged and coordinated? If so, how and with what effectiveness? Much emphasis is being given to coordination under some sort of national council: what evidence is there that these councils, if used, lead to more effective research? Do actual resource allocations to research and extension match country priorities? Does the research and extension system influence/interact with national or regional policy-making bodies? If not, are there ways that this interaction can be improved? Are any particular management systems — financial, operations, personnel, or information — being developed and utilized to more effectively support the unique needs of agricultural technology management?

Developing technology — implementing the research agenda — consists of three interrelated functions: generation, assessment, and diffusion.

Generating Technology

Technology generation is usually associated with the research function. Research can be done by public or private institutions or some combination of both. Within national research programs, tasks can be allocated to experiment stations, to farmers' fields, or both. The experiment stations can have many different roles, as can farmers' fields. The research system should be linked to the extension system and to farmers to facilitate an interactive flow of information.

National agricultural research is not an isolated effort. On the contrary, it is an integral part of a world complex of research institutions and activities ranging from basic and specialized institutions in developed (or developing) countries, through the regional networks involving groups of countries, to the international agricultural research centers. This represents a vast pool of information on which national research can and should draw to avoid repetition. National activities can also contribute to this pool of knowledge and information. Countries with small human and financial resource bases pose special problems for organizing research. The size of the research effort is essentially an economic question about what a country is able and willing

to invest. How much and what type of research is needed? Does every country need to go into all phases of research? What are the alternatives?

Borrowing, however, is not a straightforward process. Research results are seldom directly transferable from one country to another. Agricultural technologies are usually location-specific and sensitive to the agroecological and socioeconomic environments of the farmers who use them. Little borrowing is possible without some capacity to do research. To borrow effectively, it is necessary to screen and interpret possible alternatives, which requires the capacity to do research. A critical mass, defined in some way, must be present within the country; however, this does not require that all levels of research capabilities also have to be present in the country.

Questions:

Are there strong national or regional research programs for principal commodities? Is a range of biological, physical,and social science competence applied to problems in an integrated manner? How is this enforced? Is a farming systems approach used and, if so, with what effectiveness? What are the relative proportions of research carried out on experiment stations and on farms? Do farmers and extension workers participate in carrying out and evaluating the research? If so, how and with what results? Are research stations of adequate size, properly located, and adequately staffed? Are laboratories adequately equipped and used? Is there adequate transportation (including operational budget support) to permit researchers and extension agents to move about the country and, especially, to work on farmers fields?

Does the private sector play a major role in agricultural research? If so, how? What might government policy do to promote an effective private-sector contribution?

Are universities linked to the national research system? If so, how? If not, why not? Is the private sector, e.g., hybrid seed or fertilizer distributors, linked to the national research system? If so, how? If not, why not?

Is the national research program linked to the international agricultural research centers? If so, how? If not, why not? Is the national research program linked to programs in other countries or to regional networks? If so, how? What are the results? If not, why not?

What are the linkages of research to public extension? How are these linkages being developed, i.e., is there a plan? How effective are the linkages? What is the usual time lag between the initiation of research and the adoption of the results by farmers?

Assessing Technology

Technology assessment is monitoring and evaluation — does the product meet the tests of technical feasibility, economic profitability, distributional equity, social acceptability, and/or environmental soundness? In the development of technology, program designers must adopt rules for deciding which varieties and production practices to recommend as well as when and how to attempt research adjustments, that is, feedback. Such determinations can be made at different stages in the research-cum-diffusion process. Decisions can be based upon the results of analyses of yield under experimental conditions. Decisions can also be based on the results of analyses of yields achieved in farmers' fields (but under controlled conditions). A third procedure, monitoring farmer experience in the periods *after* the varieties/species and practices have been released, generally has not been a normal part of the technology development process in low-income countries. Yet potentially it is just such monitoring of the farmer as a full partner in the testing procedure that can allow on-farm research to become iterative and dynamic. And this is actually the assessment process in more economically advanced countries where much, if not most, of the plant breeding and varietal development is done by the private sector. The market actually carries out the assessment function in most developed countries. Through technology assessment, technology generation and diffusion thus can become highly interrelated, involving a two-way flow of activities from more fundamental investigations to experimentation by the farmer.

Questions:

Is there early and continuing on-farm assessment of the usefulness of particular findings and innovations generated by research? When does the assessment process begin? Who participates in the assessment? How long does the process of assessment continue? What steps are being taken to gather evidence (empirical, if possible) on the impact of the research program — policies changed, etc.? Do scientists talk directly to farming families about their technologies? Are recommendations tested under farmers' conditions? Are technologies tested on farms? By farmers? Does on-farm data actually get back to the scientists generating the technology? Is there evidence that the scientists take the on-farm experience into account in their planning their future research (i.e., is there evidence of positive feedback)? Is the role of the private sector included in assessment, e.g., promising seed lines moving to seed companies for multiplication and distribution? Are recommendations formulated and made available to farmers rapidly, with due consideration to the socioeconomic and biological risks involved?

Diffusing Technology

Technology diffusion is traditionally the function associated with extension, i.e., the transfer of technology. The full benefits of research are not likely to be realized until it is integrated with other knowledge and appropriately communicated, especially to farmers with limited holdings. Some research results have been so dynamic that widespread adoption has occurred without concerted public extension efforts. More frequently, however, there is a large gap between the potential productivity that modern localized research (integrated into existing knowledge) makes possible and the actual productivity realized by the vast majority of small farmers for whom the research has been conducted. It is essential to have effective mechanisms in place to support the integration and widespread adoption of the full range of opportunities made possible by research. This can be carried out by an extension service, by researchers through farm-level experiments, by communication over mass media, by private suppliers attempting to sell products, by farmer-example, or, ideally, by some combination of these.

Many countries have public extension agencies; how can they be made to work better? An extension system must have improved technology to extend if it is to be effective. This is basic. Other weaknesses that have lessened the effectiveness of extension services in developing countries include

- *Extension training:* Extension personnel may lack training in extension methods and communications skills.

- *Technical training:* Extension personnel may lack practical skills and training about improved agricultural technology.

- *Mobility:* Field-level extension personnel may lack adequate transportation to reach farmers effectively.

- *Equipment:* Extension personnel may lack essential teaching and communication equipment.

- *Organization:* Extension personnel may be assigned other tasks, including regulatory functions, besides extension work.

- *Linkages:* A continuing two-way flow of information between national extension organizations and research institutions may be lacking.

Some countries have yet to establish large extension bureaucracies; public extension services may not be necessary. Communication alternatives might effectively supplement or play the same role as public extension services. The private sector might play a major or supplemental role in the diffusion

process. Public policy might more effectively promote mass communication or private-sector diffusion.

Questions:

What type of organization is being used to extend agricultural technology? What parties are involved in the diffusion process — research or extension or both — and how? Is diffusion promoted by public or private institutions or both? Is improved technology available to extend? How is extension linked to research? Who sets extension priorities? What is the expected role of extension services: conveying agricultural production information to farmers and encouraging application of the same; providing an educational function, that is, seeking to change farmers in positive ways; attempting to relieve limiting factors, whatever they may be, to increased agricultural production and distribution; or promoting broadly based rural-development efforts in support of national production goals? Who supervises extension work? What skills and training do extension agents have? What kinds of teaching aids, equipment,and transportation are available to extension agents? What other work is assigned to extension agents? Is the diffusion process implemented through individual farmers or groups?

Does the communication support system within the research and extension system have adequate procedures for studying (taking into account) farmer behavior and motivation, particularly as they relate to variability and risk and for developing effective messages and communication strategies in this context? If so, how? If not, why not? Does the system have procedures that facilitate an adequate exchange of information among research, extension, and the farmer, considering the magnitude of the technology diffusion challenge? If so, how? If not, why not? Have procedures to coordinate the use of multiple channels — extension worker training, personal contact with the farmer, and a range of media — been developed and do they maximize their combined impact at acceptable cost? If so, how? If not, why not?

What role does the private sector (e.g., seed producers, fertilizer distributors) play in the diffusion process? Are there any factors that limit private-sector participation in this process? What role could the private sector effectively play? What could be done to enable it to play a more effective role?

Promoting Adequate Continuous Stable Support

Agricultural research and extension is not an inexpensive undertaking. On the other hand, economic payoffs to successful technology management systems can be high, fully as attractive as, if not more attractive than, investments in almost any other sector of the economy. Therefore, there

should be a strong incentive for government to provide financial support to the level necessary.

Technology development is a long-term process. A technology management system requires continuous, stable support if it is to prosper. Linkages between research systems and farmers have special financial implications for recurrent costs. The keys to promoting interaction and feedback are to encourage (a) researchers to work on farmers' fields and (b) researchers and farmer advisory agents to cooperate on as many levels as possible. This requires funds for travel, maintenance of equipment, and salary incentives to encourage staff to work under sometimes personally difficult, although professionally rewarding, circumstances. Planning and finance ministries have obligations to minimize the costs of programs, and recurrent costs are attractive items to prune. Yet, they are crucial to success in technology management. Often even smaller amounts of funds are allocated for maintenance.

The process of generating and maintaining broad acceptance and support of a technology management system, or any major undertaking, is doomed to failure without the understanding and support of a substantial segment of the public. A technology management system must develop a supportive clientele, a constituency (which must first be developed among the users of its findings) who will actively lend a hand in obtaining adequate, continuous support for its programs and cooperating institutions. A special obligation falls on those responsible for technology generation to communicate this message.

Questions:

Is there adequate government financial support, especially for recurrent costs, and are there good prospects for continued support? What percent of the national budget/GDP is allocated to agricultural technology management? How does this compare to five or 10 years ago? Do private interests pay for specific research programs, e.g., varietal development in tobacco? Is any other financial support contributed by local constituents, e.g., commodity cesses or provincial contributions?

How is the performance of the agricultural research and extension system judged by administrators and scientists within the system — regarding contributions to scientific knowledge, production, and/or income? How is it judged by farmers and other users? How is it judged by policymakers? Is the system responsive to performance evaluation and why? If so, how does it respond?

What measures of performance are used and how are they communicated and applied? How, and to what extent, do producers, laborers, and consumers (including lower-income groups and women) benefit from the application of the research results? What evidence is available on the impact of the research (empirical, if possible) — such as changes in policies; percent of cases in which research results are moved to the extension stage; varieties released; recommendations made; adoption over time and among economic groups; yield, production, nutrition, and income changes over time and among economic groups? How is this evidence measured? Are empirical data on adoption, production, nutrition, and other relevant indicators of performance regularly collected? How and by which institutions? Have there been any unintended positive or negative effects on target groups? Is the information effectively fed back into the system and used in decision making?

Concluding Comments

When one is requested to analyze a program for agricultural research and/or extension, on what should he/she focus in order to make the greatest impact? This paper suggests a way to develop promising means of improving the operation of a system by identifying and systematically assessing key activities (the pressure points of agricultural technology management) and reviewing alternative ways that the activities might be implemented.

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APPLYING ATMS APPROACHES IN WIDELY DIFFERENT SYSTEMS: LESSONS FROM ISNAR'S EXPERIENCE

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Abstract

This paper discusses the wide adaptability of the agricultural technology management system (ATMS) approach using ISNAR's experiences in both Latin America and the Middle East as examples of its applicability, usefulness, and potential difficulties. The ATMS approach may be considered a contingency and systems approach: It attempts to understand the interrelationships within and among organizations as well as the relationship between the individual organization and its environment. It attempts to understand how organizations operate under varying conditions and in specific circumstances and is ultimately directed toward suggesting the organizational designs and managerial actions most appropriate for specific situations.

Introduction

There have been many attempts to measure the impact of agricultural research investments or to look at the functioning of agricultural research systems. There have been relatively few attempts, however, to bring the two types of analysis together in a way that identifies opportunities to improve research systems and increase the impact of agricultural technology management efforts. This paper attempts to provide a framework for doing this. It draws on work that ISNAR and Rutgers have done together in elaborating the concept of the agricultural technology management system (ATMS) and illustrates both the usefulness of the approach and its limitations with examples from subsequent ISNAR experiences (Elliott et al. 1985).

ISNAR's goal, as expressed in its strategy statement, is "to assist developing countries to improve the effectiveness and the efficiency of their agricultural

research systems through enhanced capacity in the areas of research policy, organization, and management" (ISNAR 1987). This means that ISNAR's primary focus must be the national agricultural research system (NARS), but its systems approach leads it on occasion to place the NARS within a broader environment — the agricultural technology management system. The objectives of this paper are

1. to present a conceptual framework for identifying opportunities to improve agricultural technology management systems;

2. to describe certain tools that have been used to assist in identifying such opportunities and choosing among them;

3. to relate this analysis to commonly used frameworks for strategic planning at the system level;

4. to illustrate cases where proper application of such an approach can improve the nature of recommendations made.

Some System Concepts

Churchman (1979: 29) defines a system as a "set of parts coordinated to accomplish a set of goals." He identifies five basic considerations that the scientist must keep in mind when thinking about the meaning of a system:

1. the total system objectives and, more specifically, the performance measures of the whole system;

2. the system's environment: its fixed constraints;

3. the resources of the system;

4. the components of the system, their activities, goals, and measures of performance;

5. the management of the system.

The approach taken in the present ATMS study is generally called a "contingency" approach. It attempts to understand the interrelationships within and among organizations as well as the relationship between the individual organization and its environment. It attempts to understand how organizations operate under varying conditions and in specific circumstances. It is ultimately directed towards suggesting the organizational designs and managerial actions most appropriate for specific situations. In short, it says there is no one best way of organizing and managing research systems, i.e., that

there is a middle ground between trying to apply "universal principles" and saying "it all depends" (Kast and Rosenzweig 1985).

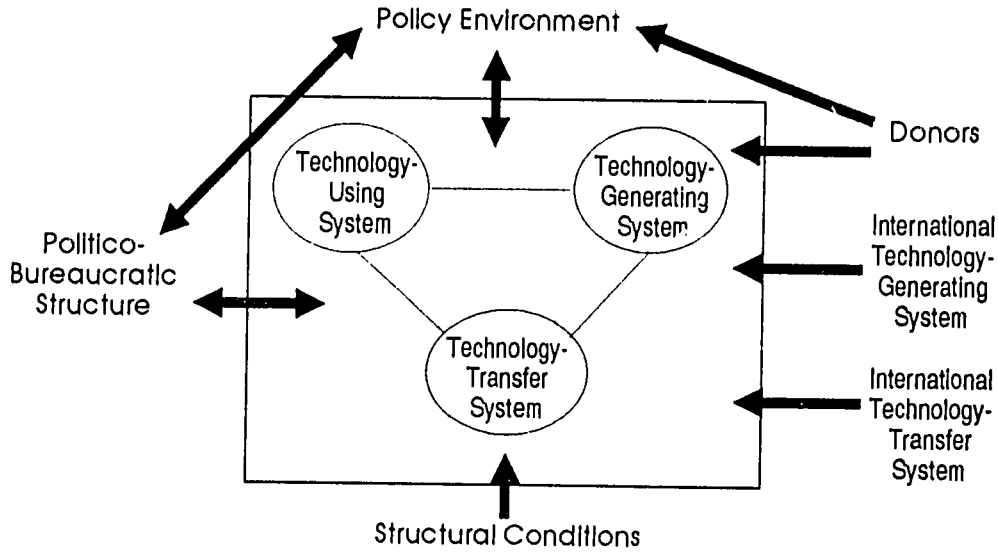
The Agricultural Technology Management System

The need to look at the entire technology management system stems from the fact that policymakers are not interested in research per se; they are only interested in the technology that research can put at the disposal of farmers. This is especially true when one recognizes that future agricultural development will be science-based rather than resource-based. Horizontal expansion of areas under cultivation or simple increases in capital and labor are no longer sufficient to meet the demand for sustainable production and food security. The choice of technology will be even more critical in those areas where there is the need to "park a generation on the land" until other development can ensure incomes and employment that will provide access to food.

Every country has an ATMS, whether consciously or only implicitly defined. Since a system is defined first and foremost by its objective, we have defined the ATMS as comprising all institutions, individuals, and their interdependent relationships aimed at the generation, assessment, and diffusion of improved agricultural technologies in order to increase agricultural production and incomes" (Elliott et al. 1985). In order to attain this objective, the ATM system must be able to access agricultural knowledge, transform it into technologies that meet the expressed goals of the system, and transfer these technologies to end users. A research system produces only a potential for agricultural gain; its interactions with the technology management system ensure that this gain is realized. By "agricultural technology management" we mean that the component parts of the system, individually or collectively, are able by some management means to deal with the constraints to the system, either by adapting the system to its constraints or by attacking the constraints directly. Thus, improvement in the ATMS implies that the system is able to endogenize some of the constraints that were previously part of its environment.

A generic ATMS which places the component parts of the system in relation to each other is described in Figure 1. The component parts of an ATMS are listed below:

- the "technology sector," with its subsectors (the technology-generating sector, the technology-transfer sector, and the technology-using sector);
- the politico-bureaucratic structure, composed of formal representatives of the government and decision makers, and the channels through which the interests of all groups in the system are made known to policymakers;



Source: Elliott et al. (1985: 34).

Figure 1. A generic ATMS

- the "external sector," composed of donors, international technology-generating institutions, and multinational firms engaged in technology generation and transfer;

- the underlying "structural conditions," which include world markets for inputs and outputs, the resource base of the country, and the initial distribution of resources and power;

- the "policy environment," made up of all laws, regulations, customs, and practices that limit the way in which components of the technology sector behave.

A Three-level Analysis and Its Associated Tools

The ATMS approach was developed first for use in Latin America, where the public sector had a pervasive impact on both the supply of and demand for agricultural technology. In spite of significant investments, some systems have not been very productive, and in many cases, the private sector has been emerging as an important force. Reconciling competing theories of the evolution of technical change in Latin American agriculture led to our three-stage analysis, which is able to deal with all the issues raised by these theories, which include the following:

1. induced innovationists, who explain the development of inappropriate technology by incorrect market signals;

2. structuralists, who emphasize the role of land distribution in producing biased technical change;

3. political economists, stressing the role of special-interest groups;

4. monetarists, emphasizing incorrect exchange rates and pegged interest rates in inflationary situations;

5. technological determinists, describing the role of external organizations and the international transfer of technology;

6. institutionalists, focusing on management weaknesses within the research system.

All of these approaches emphasize different factors that affect the nature and quantity of improved technologies, both supplied by the agricultural research system and demanded by users of those technologies.

From the perspective of the supply of technology, the ATMS model looks at the system's research resources, component units, internal management, and its attempts to influence its environment. From the point of view of the demand for technology, the model postulates that the nature of technology demanded is conditioned by a number of structural conditions and policy constraints that limit the range of options open to farmers of different classes. Some of these constraints, through improved technology management, may be changed.

The ATMS approach involves three levels of analysis that are logically linked to one another and are iterative in their contribution to identifying opportunities to improve the system. It begins holistically but focuses rapidly on the key points of intervention: (1) at the system level, (2) at the institutional level, and (3) at the commodity level.

The information generated at each succeeding level is used to confirm hypotheses advanced at higher levels and is available when strategies for improvement in the technology management system are formulated.

Stage 1: The System-Level Analysis

The Stage 1 analysis is the most aggregative level and generates information and hypotheses about the influence of key environmental variables, primarily the structural constraints and policy environment. It fully describes the

system and its evolution. It includes the following tools and products, as shown in Table 1.

Table 1. The System-Level Analysis

Analysis	Tools and Products
Functional	Responsibility charts for key organizations in the ATMS, providing a complete mapping of the system's structure and management mechanisms.
Events	Major policy, institutional, and technological events in recent history of the system, providing a chronology of the system and the interrelationship between policy, institutional, and technological events.
Policy	Key policies that affect the overall level of economic activity in the system, relative prices of factors and outputs, and direct investments in the agricultural sector.

Stage 2: Institutional Analysis

The institutional analysis focuses only on the few key organizations within the system that are concerned with technology generation for agriculture. As a component of the ATMS, each organization can be approached (as a subsystem) in terms of its mandate, objectives, resources, and the management of both its internal functions and the outward linkages to its environment. In many ways, an ISNAR review of a national agricultural research institute concentrates on this level of analysis. The key functions that the analysis looks at are

- identifying problems;
- setting priorities;
- obtaining adequate financial support;
- attracting and retaining human resources;
- developing and managing infrastructure;
- programming and executing research;
- managing linkages with the technological environment;

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- monitoring and evaluating research;
- communicating results to clients and policymakers.

It is at this level that we begin to look at the management issues that are basically under the control of directors of institutes (including the way they manage their relationships with the broader ATMS).

Stage 3: Technology Performance Analysis: Case Studies and the Intervention Opportunity Matrix

This third level of analysis brings us to the disaggregated level of the individual commodity and an attempt to assess the impact of technology management activities related to one crop. Case studies on carefully selected commodities are carried out using an integrating framework which we call the "Intervention Opportunity Matrix." At its simplest, this is a checklist of factors that either constrain or have a positive influence on the path of technological change at the level of the individual commodity. In its more complex form, one can attempt to quantify the variables.

It is at the level of the individual commodity that hypotheses about the adequacy of resources, management, or the impact of external factors are confirmed or disproved. It is, for example, quite conceivable that a system, which in the aggregate is underfinanced and understaffed, may manage to give stable funding, continuously allocate its best scientists to its most important commodity, and achieve an impact.

For each selected commodity, covering the principal food, export, and industrial crops, a number of technological events are studied in detail. The impact on production is estimated, and each factor is assessed as having contributed positively or negatively to the impact on production (Elliott et al. 1985).

Looking across the range of technological innovations and commodities, one can see the extent to which research resources, management, farm-level constraints, structural conditions, and the policy environment have been constraints on or contributors to success in generating and diffusing improved technology.

The Stage 1 (System-Level) Analysis and Strategic Planning

The Need for Coherent Values and Structures

The contingency approach leads us to search for structures, processes, and incentives that are compatible with the known strategic objectives of the

system and that are feasible within the system's environment. When the goals of a system change, its structures, processes, and resources must often change as well. A system that aims at producing export crops grown in monoculture, organizes its scientists by discipline-based departments, and promotes its scientists for publications in learned journals will behave quite differently from one that aims at regional development, organizes its scientists in farming systems teams, and promotes its scientists on the basis of their contributions to a team. This example clearly indicates that the structures and management mechanisms of a system should be determined after the establishment of the system's objectives.

The structures of NARS are frequently changing in response to changed mandates or in response to changing environments. Colonial systems in Africa were oriented towards export commodities (in an era when the majority of the population was rural and food security was not a problem). Agriculture was called upon to provide tax revenues, generate export receipts, and create a market in rural areas for import substitution industries. However, there has been growing concern about the ability of traditional systems of cultivation to satisfy both rapidly escalating national food requirements and targets for industrial and export crops. In this light, the appropriateness of the dominant commodity-oriented organizational structure of agricultural research, in particular in the francophone countries, has increasingly been called into question.

In many respects, the success of the commodity-specific approach to research and development (e.g., cotton in Mali and in the northern Ivory Coast) brought these countries to a point where the main cash crop was constrained by limited productivity in important key food crops. This called for a more integrated approach, that would give particular attention to food crops. To some extent, it was this shift in agricultural development (and thus agricultural research) priorities that provided the major impetus for the coordination, and sometimes nationalization, of agricultural research organizations in francophone West Africa from the mid 1970s onwards.

It is interesting to note the way in which different countries have restructured the inherited institutes in francophone Africa. The original commodity institutes, with their upstream links to French parents and downstream links to semipublic technical assistance companies (which carried out extension), operated commodity networks across African countries. They functioned largely in isolation from one another within given countries, and the evolution of national systems arising out of these institutes has taken different paths in different countries. There was an initial attempt by African governments in the late 1960s and early 1970s to exercise national control over foreign-financed and -directed institutes through the creation of ministries of scientific research. This was later followed by concrete steps

to create fully national systems. Some countries created a single national institute; some created specialized institutes organized along broad ecological zones; some absorbed research within a department within ministries of agriculture; and some divided research among separate cropping and livestock institutes. Table 2 shows the directions taken by different countries.

Table 2. Types of Nationalization of Agricultural Research Organizations among the Countries of Francophone West Africa

Type	Countries
1. Creation of a department/ "direction" within a ministry	Benin/CAR/Chad/Congo/Togo
2. Creation of specialized research institutes	Burkina Faso (CRTA), Cameroon (IHS) Senegal (ITA), Togo (INRS)
3. Creation of "transitional" specialized research institutes	Ivory Coast (IDESSA) Senegal (CNRA, CRODT)
4. Creation of several, broad-mandate national research institutes	Burkina Faso (IBRAZ/IRBET) Cameroon (IRZ/IRA) Mali (IER/IONRZFH) Mauritania (CNRADA/CNERU)
5. Creation of single national research institute	Ivory Coast (INIRA), Niger (INRAN) Senegal (ISRA)

Source: Rocheteau et al. (1988).

Although the ATMS approach is not used deterministically, in each of these cases, it can help explain the evolution of system structures as a response to basic economic constraints, political forces, and external influences.

In East Africa as well, the breakup of the East African Community led to the takeover of institutes, originally designed for a regional mandate, by the countries in which they were located. The result was a need to support excessive infrastructure and staff with national resources that were inadequate for maintaining the institutes at their former level. This pattern was repeated in the West African cocoa and oil palm research institutes which are now part of the national systems of Ghana and Nigeria, respectively. Structures became inappropriate for the national goals they had to serve.

Finally, restructuring may be necessary because of changing political situations. When a country goes from a highly centralized political system (often military) to a more decentralized political system, there is often an accompanying decentralization of planning, financing, and decision making in

agricultural research (e.g., Spain, Argentina). In short, change is pervasive in all systems and the country must engage in strategic planning to cope with such changes.

Strategic Goals and Action Plans

We now concentrate on the role of the Stage 1 (system-level) analysis in generating hypotheses about system-level constraints and in providing the information required to assess alternative proposals for improving the overall ATMS.

A strategic planning process involves three steps: (1) an assessment of the present scenario and its critical problems, (2) the generation of a range of alternative solutions from which a preferred scenario is chosen, and (3) the establishment of the action program and choice among the strategic options for implementation. In many cases, the strategic planning process is faulty because action-oriented managers jump from the problem to action without considering the range of alternative scenarios. The tools developed in the ATMS approach lend themselves well to steps 1 and 2 (assessing the present scenario and considering the options). One cannot effectively jump from step 1 to the final recommendation.

The Functional Analysis and Responsibility Charting

The mapping of the ATMS is carried out using a modified form of a project-management tool called a responsibility chart. The responsibility chart identifies all relevant actors in a particular project, describes their roles, and determines the level of responsibility they have with respect to a particular function (e.g., "makes final decision," "must be consulted," etc.). In applying this tool to the ATMS, we identify the key organizations or classes of participants, describe their principal mandates and places within the system, and assess their level of participation in each of 13 key functions that the system must be able to perform (or at least influence in its own behalf). Having determined the level of participation, we describe the mechanism by which the organization participates in the function.

The 13 key functions of the ATMS are

1. defining macroeconomic strategy;

2. determining the intersectoral allocation of resources;

3. developing human resources for the agricultural sector;

4. generating domestic political support for agricultural research;

5. generating external support for research;

6. setting clear goals for the agricultural sector;

7. allocating resources within the agricultural sector;

8. determining agricultural research strategies;

9. generating and assessing technology;

10. transferring technology;

11. providing support services to technology adoption;

12. evaluating the impact of technology development efforts;

13. ensuring the marketing and use of the product.

All of these functions can be associated with the various resource, management, and external variables discussed above.

We can illustrate this with a responsibility chart from the case study of Panama. Tables 3 and 4 show responsibility charts for "generating" and "transferring" technology (two of the 13 functions described).

The responsibility chart provides three ways of looking at a system:

1. the "structural" (number of organizations involved in the system and their mandates);

2. the "functional" (the critical functions of the system and how they are carried out);

3. the "operational" (the mechanisms that are used to perform these functions.

The concentrated technology-generating sector in Panama contrasts with the fragmented and overlapping activities of various organizations performing technology-transfer functions. Many organizations took on such functions in the vacuum created by the abolishment of the extension service during the reform of the late 1960s.

There are three principal advantages of constructing responsibility charts:

Table 3. Panama: Responsibility Chart — Generation of Technology

Institution	Role	Mechanism for Participating in Technology Generation
MIDA	coordinate	Overview of agricultural sector
MIPPE	none	none
Legislature	finance	none
ORP	none	none
CAN	none	none
CAR	none	none
CAL	none	none
Crop Commiss.	none	none
BID	none	none
USAID	finance	support to IDIAP, previous support to FAUP
CIID	finance	technical assistance in dual purpose livestock
IICA	none	none in generating sector
World Bank	none	none
IMF	none	none
IDIAP	decide/exe	on-station and on-farm research
FAUP	execute	research stations, on-farm research
CIMMYT	execute	provide germplasm, research methodology,IDIAP/FAUP
CIAT	partic.	CIAT approach: germplasm for acid soils strategy
CATIE	partic.	Rice farming systems Baru, technical assistance
CIP	execute	research on station, support to PRECODEPA
Rutgers	partic.	Rutgers staff in onions, potato, pastures, cattle
ISNAR	partic.	nascent collaboration in economic studies
Chemonics	none	none
SENEAGRO	partic.	proposed role in farm-level trials; validation
BDA	partic.	BDA gerente is member IDIAP Junta Directiva
BNP	none	none
Private Banks	none	none
ENASEM	none	none
Seed Companies	none	none
Input Suppliers	none	none
ANDIA	none	none
COAGRO	none	none
IMA	none	none
ISA	none	none
ENDEMA	none	should be link to IDIAP for mechanization
IPACOOP	none	none
Pioneer Seed	execute	hybrid seed produced for sale in Latin America
Citricos	execute	abandoned disease research, 4 ha varietal trials
Nestle	partic.	provide land and labor to test IDIAP material
United Brands	execute	research on station with production interest
Corp Bayano	none	none
SONA	partic.	field-level trials of technology
ANAGAN	none	none
CONAC	partic.	some asentamientos collaborate in on-farm trials
Arroceros	finance	rice tax partially allocated to research
Low Income Farm	partic.	on-farm trials in IDIAP/FAUP programs
Small Farmers	partic.	on-farm testing of IDIAP/FAUP material
Large Farmers	none	none
Asentamientos	partic.	on-farm testing on some asentamientos
Molineros	none	none

Table 4. Panama: Responsibility Chart — Transfer of Technology

Institution	Role	Mechanism for Technology Transfer
MIDA	decide	see SENEAGRO
MIPPE	execute	Integrated Rural Development project under MIPPE
Legislature	finance	finance
ORP	none	none
CAN	none	none
CAR	coordinate	theory: coordinate credit, extension, input support
CAL	coordinate	coordination at micro level of intervention
Crop Commiss.	none	none
BID	none	none
USAID	finance	Chemonics in SENEAGRO, Education for Rural Development
CIID	none	no role in transfer beyond on-farm trial impacts
IICA	none	none
World Bank	none	none
IMF	none	none
IDIAP	partic.	on-farm research, diagnostic studies, documentation, communication methods
FAUP	execute	on-farm research, materials for SENEAGRO, courses
CIMMYT	partic.	on-farm research, germplasm IDIAP/FAUP
CIAT	partic.	livestock program works on farm
CATIE	partic.	on-farm research
CIP	none	none
Rutgers	partic.	work with Seneagro on-farm programs, large farmer
ISNAR	none	none
Chemonics	execute	develop transfer methodology
SENEAGRO	execute	field agents, local committees, extension material
BDA	execute	technical assistants enforce norms as condition
BNP	partic.	agricultural agents supervise loans, techniques
Private Banks	none	none
ENASEM	execute	production, storage, certification of seed
Seed Companies	partic.	link to producer associations, sales to clients
Input Suppliers	partic.	sales agents contact farmers, advertise, recommend.
ANDIA	inform	through individual member companies
COAGRO	none	none
IMA	none	none
ISA	partic.	enforce technical recommendations as condition
ENDEMA	none?	work with other public agencies
IPACOOP	partic.	provide some technical assistance beyond management
Pioneer Seed	partic.	literature, recommendations for local distributors
Citricos	execute	request SENEAGRO agent to help outgrowers (pina)
Nestle	execute	tech. assistance, fix planting dates, purchase quotas
United Brands	execute	technical services to associated outgrowers
Corp Bayano	partic.	some extension to farmers in project area
SONA	execute	2000 families reached (76%), 12 crops covered
ANAGAN	partic.	organize demonstrations with IDIAP
CONAC	partic.	asentamientos one-time target of MIDA services
Arroceros	inform	technical publications for members and government
Low Income Farm	partic.	targets of transfer and research efforts
Small Farmers	partic.	targets of area development, crop programs
Large Farmers	partic.	on-farm testing, targets of private efforts
Asentamientos	partic.	MIDA agents concentrated on asentamientos 1972-82
Molineros	partic.	seed distribution, credit

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1. They make very explicit the hypotheses about the role and behavior of institutions within and outside of their principal mandate areas.

2. They point out the presence of superfluous institutions (or alternatively, the absence of essential actors) with respect to each function.

3. They help suggest alternatives for improvement that may be of a structural nature (combine institutions, create new ones) or of a managerial nature (strengthen the mechanisms for performing the function through more resources, additional meetings, more permanent staff, etc.).

In this respect, the information helps lay out the range of alternatives from which a preferred scenario may be chosen.

With respect to the Panamanian ATMS, we identified several critical weaknesses:

- Few agricultural institutions influence agricultural policy.
- The system is complex and fragmented.
- There is an absence of mechanisms for establishing policy.
- Real coordinating structures are different from the formal ones.
- External assistance is uncoordinated.
- The system is isolated from domestic support.
- Fragmentation leads to some duplication, and even contradiction, in the messages reaching farmers.

From these observations, hypotheses about alternative structural and management improvements were formulated, carefully taking account of the target farmers to be served and the historical autonomy enjoyed by various parastatals involved in the sector. This history limits the degree of centralized direction the system will permit.

Limitations of the Functional Analysis

By itself, functional analysis is only a static map of the system which helps identify institutional and functional gaps in the system. Several criticisms have been made about its application, and these bring out its limitations.

First, it has been noted that there is a danger that it could become "reductionist" (Marcotte 1988). Recommendations may appear to be based on preconceived notions of what is organizationally necessary and may stress what the analyst believes to be the critical areas for his/her agency's involvement. This is a danger that exists in any approach. In the case of the functional analysis, the need to categorize institutions by their mandates and make explicit their involvement in key functions is more likely to reduce than to accentuate this danger.

Second, the approach is one that does require an intimate knowledge of the system being studied, especially where formal and "real" systems are being compared. For this reason, it is an approach that is best applied by an experienced participant in the system. Once the mapping is completed, it can be checked with other informants as to the accuracy of the observations about individual organizations — their level of involvement in each function and their mechanisms for participation. The advantage of the approach should lie in its transparency and the ability of readers to validate the analysis for themselves. Without such transparency, and an explicit discussion of alternatives, recommendations may appear to have little to do with the analysis itself. Transparency is required if the ATMS approach is to help decisions about whether improvements should lie in changing structures, changing processes, or increasing resources allocated to a given function.

In a recent analysis of the ATMS in the Sudan (Arab Organization for Agricultural Development and ISNAR 1988), an attempt was made to map out the system. A clear listing of the organizations involved in the ATMS (over 100) indicates that the system is both complex and fragmented. This structural view is in itself useful. However, the processes (mechanisms) that each organization employs to participate in the 13 functions are still not made sufficiently explicit in the text for the tentative recommendations to be evident to readers. It is for this reason that the approach calls for a national workshop on the study's findings so that observations can be corrected and, more important, a range of alternatives for improvement can be examined before final recommendations are made.

One example should be sufficient to demonstrate the need for open discussion of the findings before final recommendations are made. It is argued in the Sudan study that (1) a clear policy is needed to translate national objectives into a research program, (2) an absence of clear research policies exacerbates the fragmentation of the system, (3) technology-generating institutions have no input into the policymaking process, and (4) technology-generating organizations do not presently have the capacity to do so. It would seem intuitive to make recommendations to strengthen the capacity of the technology-generating institutions to make an input into policymaking, as well as creating a body with clear responsibility for policymaking.

However, a number of intermediate premises need to be made clear: (1) that policy decisions would be based on technical advice if it were available, (2) that a formal or informal body for policymaking does not already exist, and (3) that the solution lies in making structural improvements for coordinating policy (i.e., creation of an agricultural research council), rather than in improving the mechanisms that set up programs or invest additional resources in existing processes and structures. These alternatives will certainly be discussed in the national workshop.

The Historical Perspective: An Events Analysis

A static map of the system is inadequate if we are going to make recommendations for a dynamic situation. Let me turn, therefore, to one of the tools used in the Panama case study which provides an historical perspective on institutional improvements studied at the disaggregated level of the individual technological event.

The events analysis is a methodology for systematically recording and analyzing information about significant events in the development of an agricultural research and technology management system (Elliott 1987). It uses a relational data base management program to explore the relationships among technical, institutional, and political factors associated with individual events. By cross-referencing different types of information, we can not only identify patterns of interaction, but also — at any moment — provide supporting evidence drawn from a wide variety of sources.

An "event" is essentially defined by the fact that someone has cited it in the literature or in conversation as being important in illustrating some point about the system. Once recorded and accurately described, it may be recovered and used in other contexts and may bring out relationships that would not have been apparent when it was considered in isolation.

For each event, the following information was obtained and recorded in the data base program:

- a description of the event, e.g., introduction of CIAT germplasm;
- the nature of the event (agronomic, biological, chemical, mechanical, economic, institutional);
- the crop to which the event relates;
- the year the event took place;

- the sector in which the event originated (public or private, external or domestic);
- the organization principally responsible;
- the sector of the ATMS to which the principal organization belongs;
- collaborating organizations;
- the sector to which the collaborating organizations belong.

With such information on literally hundreds of events, one is able to carry out the following analyses:

1. a chronology of technological events by commodity, their nature, and the characteristics of the participating institutions;
2. an analysis through time of the interaction between classes of institution (public and private, university and research institute, donors and private sector, etc.);
3. a chronology of major institutional changes or principal policy changes in the system.

This historical perspective, which again is most easily carried out by a local study team, generates the base of information needed to assess the feasibility of alternative policies or organizational structures, some of which may have been attempted before under the same or different circumstances. The simple chronology of events in pastures, shown in Table 5, brings out the change in strategy that accompanied a change in donors and the interaction between the public, private, and international donor sectors.

A separate chronology of events in rice (not presented here) indicated clusters of technological events of the same type (early reliance on mechanical and chemical innovations in the 1940s and 1950s prior to the Green Revolution in the 1960s — which emphasized biological improvements). The private sector was associated with those mechanical and chemical innovations, and the public institutions were more involved with the latter.

The Policy Analysis

The third tool in the Stage 1 analysis looks at the implications of key macro policies for the agricultural sector. The technique is to identify those policies that affect the level of economic activity, relative prices of agricultural

Table 5. Panama: ATM Events in Pastures

Year	Case	Nature	Description of Event
1953-54	pastures	biol	Controlled introduction of forage
1962	pastures	agron	FAUP introduces and evaluates species at Tocumen
1968+	pastures	agron	Priorities shift to legume crops for forage
1968-72	pastures	agron	FAO/Minag introduce and test forage species at Gualaca (high-input approach)
1968-76	pastures	agron	FAO/MAG work on high-input pasture, frequency of cutting, fertilization
1972-75	pastures	agron	IICA-CATIE give priority to utilization and systems of production
1979	pastures	biol	Introduction of new species (*Andropogon gayanus*) with BNP, FAUP, CIAT
1980+	pastures	econ	BNP, Nestle, BDA make credit available for improved pastures
1983	pastures	biol	CIAT-Rutgers program fucuses on germplasm for acid soils, seed multiplication
1983	pastures	educ	One IDIAP researcher receives training at CATIE
1983+	pastures	educ	Eight of 15 researchers receive short-term training at CIAT pastures program

inputs, factors of production, and outputs, and that also reflect key policy decisions for direct investment in technology generation and transfer.

The key variables that operate at the macro level are obviously the exchange rate and the level of government involvement in the sector. Policies influencing the real cost of imported chemicals and equipment, the wage rate, and the real rate of interest will influence the nature of technology demanded.

Table 6 shows the key policy variables that were seen to be important in the case of Panama. The analysis identifies the policy and assesses its impact on the agricultural sector. At the same time, it explains the reasons for the existence of such a policy (often to serve interests outside the agricultural sector). By recognizing that some policies are unlikely to be changed in order to facilitate the generation and diffusion of improved technology, one can avoid recommendations that are not likely to be implemented.

A mission that is sent to review the ATMS system and its impact is not in a position to carry out original policy research. However, it is able to identify those policies that are likely to become the "key logs in the jam."

Table 6. Panama: Implications of Key Macro Policies for the Agricultural Sector

POLICY	INTENTION OF POLICY	IMPLICATIONS OF POLICY FOR AGRICULTURE
Use of US dollars as currency	Stability of exchange rate, facilitate international service economy, self-generated inflation impossible	1. overvaluation of dollar hurts export and import substitution; 2. facilities importation American chemicals, equipment; 3. exchange rate offers no protection from American producers; 4. compensating measures required for agriculture; 5. research essential to attain U.S. levels of productivity.
Reduction in budget deficit	Containment of government expenditures on bureaucracy	1. compression of government budgets for public agricultural sector; 2. makes recruitment of new research staff difficult; 3. budget cuts may tend to fall on operating budgets rather than personnel.
Liquidation of state-owned enterprises	1. reduce budget dificit; 2. liberate investment funds for other purposes	1. closing of sugar mills; 2. review of Citricos de Chiriqui; 3. refrain from creating new public enterprises.
Revise labor legislation	1. social policies of 1970 gave Panama high labor costs; favorable 2. less favorable interpretation of labor code; 3. facilitate the structural adjustment process	1. power of unions in agricultural industries may be reduced; 2. restrictive practices in food industries may be lightened (e.g., milk, tomato, bananas); 3. more flexible hiring and firing practices may generate more employment.
Reinterpret Agricultural Incentives Law	1. progressive dismantling of protection by quotas; 2. self-sufficiency must be at world prices	1. privileged situation of certain crops will be reduced; 2. increased emphasis on cost-reducing technology; 3. increased attention to non-traditional exports.
Revise incentives to agricultural capital	1. reduce credit subsidy for agriculture; 2. review tax exemption for imported equipment and inputs	1. exchange rate and import legislation favored over-capitalization of of agriculture; 2. research oriented towards meeting needs of mechanized farmers.
Expenditure on agriculture	1. relatively high expenditure on agriculture in relation to Agricultural Value Added	1. high expenditure ratio due to relatively small sector; 2. expenditure has not produced high productivity; 3. expenditure in form of subsidies, bureaucracy, and government enterprise; 4. reform of expenditure pattern sought by donors.
Creation of Science and Technology Unit, MIPPE	1. defence of research as necessary function; 2. monitoring of resources devoted to research	1. recognition that science and technology research is inadequate; 2. recognition of need to coordinate research policy among sectors; 3. forum for debate of agriculture versus other sectors.
Credit Policy	1. public sector credit small portion total; 2. differentiated clientele	1. public credit targeted to small and medium farmers; 2. donors have favored specialized credit; 3. private banks select prime customers; 4. government use of credit as means of directing production is weak tool.

Stage 3: Technology Performance Analysis and Implications for Institutional Change.

It is at the level of the individual commodity that we were able to validate the hypotheses formulated by the system-level and institution-level analyses. Commodity case studies were selected because of the particular commodity's importance to the system, its ability to illustrate variation among institutional priorities and policies, and its ability to reveal the strengths and weaknesses of the system. In all cases, the commodities were those in which research had played an important role in technological change.

In the analysis of technology performance, the unit of study is the individual technological event associated with a chosen commodity. One "event" might be the introduction of CIAT rice varieties; a second might be the development of national varieties with blast tolerance. Looking at yield gains (or cost reductions) and the extent of adoption, an estimate of the "success" of the innovation can be obtained. While there are possible biases in the measurement of *success*, the objective is to focus on the factors that explain the *success* or *failure* of an innovation measured in this way. Through interviews with scientists and research managers, we traced the innovation through the system, highlighting the role that research resources, research management, policy decisions, the farm production environment, and external forces had on the success of a technology.

Twelve case studies of innovations in five commodities gave sufficient variation in experience to draw major conclusions that were compatible with the hypotheses formulated at the Stage 1 and Stage 2 analyses.

A comparison of the cases of rice and maize is illustrative. Both commodities received priority attention from research. Both were staffed by excellent scientists in close contact with international centers. Scientifically, both programs achieved some measure of success. However, they were participants in completely separate subsystems of the ATMS. Rice production was concentrated geographically in the hands of large farmers or in the *asentamientos*. Guaranteed prices, import restrictions, and marketing interventions all had a major impact on the level of production, distribution of gains among participants, and the nature of technology used. Even small farmers used capital-intensive techniques, including aerial spraying and seeding. On the other hand, maize was more geopraphically dispersed, produced by farmers at different levels of technology, and influenced less by marketing interventions. Licenses to import hybrid seed for large farmers and feed for the poultry industry were given freely. Thus, the market conditions for development of small farm production were quite different from the case of rice. In both cases, the nature of the interventions has reflected the interests of the commercial sector, a dominant force in Pana-

ma's service economy. The pattern of technological development reflects these forces.

Generalizing across the many case studies, we found the following:

- Socioeconomic constraints (particularly price and marketing interventions) were cited repeatedly as severely inhibiting technological change.
- There was a fragmentation in agricultural policy with inconsistent policies practiced across commodities. However, these inconsistencies could be explained in terms of the power relations in the ATMS.
- Human resource and research management have not been a constraint in the case of the technologies studied.
- Inputs received from the international community have been positive and pervasive in their influence on technological change. Management of the relationship with the international community has not been a problem.

The implications for improvement at the system and institute levels are clear:

- There is a need for a coherent national policy for the agricultural sector.
- Both the structures and the processes for making agricultural policy require improvement.
- Interactions with international and regional organizations are fundamental to success in technology management. Policy reform rather than management improvement seems to be the critical need.

Lessons from ISNAR's Experience

In this paper, I have attempted first to describe the three-stage analysis of an agricultural technology management system. The analysis begins with a system-wide look at key policies, structures, and management processes. It then descends one level to look at key institutions and their internal functions and finishes with a detailed look at particular technological events within specific crops. The method is iterative, and information at each level serves to confirm or revise conclusions reached at the other levels.

The lessons of a methodological nature can be summarized briefly:

- The system and contingency approach can be applied to a wide range of situations and yet result in recommendations that are specific to the case being studied.

- The three-level analysis (system-institute-commodity) ensures a check on the hypotheses and conclusions formed at each of the other levels.

- Information in the functional analysis must be collected and presented rigorously, preferably by a knowledgeable person from within the system. It cannot be collected mechanically.

- Feedback from knowledgeable persons (or affected parties) is important. A workshop (an open forum) for this purpose should always be part of the methodology.

- The functional analysis can help point out weaknesses in the present scenario, and also help examine a number of alternative scenarios for improvement.

- The analyses of events and technology performance provide the dynamic view of technology management efforts that is needed for realistic recommendations.

- Selecting the "best scenario" and determining the path for getting there requires detailed institutional analysis.

- Finally, the ATMS is only an aid to thinking about system building. The process of applying it is equally important. It should be collaborative — those affected by its findings should participate through frequent feedback, and the reasoning should be transparent.

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ANALYZING AGRICULTURAL TECHNOLOGY SYSTEMS: SOME METHODOLOGICAL TOOLS

Burton E. Swanson, Carolyn M. Sands, and Warren E. Peterson

Abstract

This paper summarizes the major findings of a four-year study to develop systematic procedures for analyzing agricultural technology systems. The two primary analytical methods that were developed are described. The overall analytical framework consists of four major subsystems: technology policy, development, transfer, and utilization. These subsystems are broken down into 16 indicators, and their corresponding measures are used to assess the key input, activity, and output functions of each subsystem. The second method uses a flow analysis to describe or map the functional linkages that integrate the technology system. This technique is used to identify institutional constraints that block or restrict the flow of technology to farmers. The analysis focuses on generic, chemical, and agronomic practices, and other categories of technology within individual commodity systems. Examples of how these analytical tools have been used to assess national systems are drawn from case studies in Ecuador, Malawi, Mexico, and Taiwan.

Introduction

In 1984, an interdisciplinary research team at the University of Illinois began to formulate a practical instrument for the diagnosis of constraints in national agricultural technology systems.[1] The diagnostic instrument was

[1] This research project and related activities were carried out by the International Program for Agricultural Knowledge Systems (INTERPAKS), Office of International Agriculture at the University of Illinois, Urbana-Champaign, under partial funding from the United States Agency for International Development, Cooperative Agreement No. AID/DAN-4148-A-00-4004, entitled "Technology Development and Transfer Systems in Agriculture." Established in 1982, INTERPAKS involves a unique mix of six fields of study, which together bring a more balanced, integrated, holistic approach to understanding the development, transfer, and use of agricultural knowledge.

referred to as the "Analytical Framework." It consists of three major parts: an a priori systems macro-model, a set of methodological tools, and an analysis based on flow-system models. Throughout the planning and research, the project has been guided by a systems perspective; that is, governed by the concept that agricultural technology systems function as complex, holistic entities composed of subsystems, elements, and linkages. This approach has provided the best means of mapping complex and large agricultural technology systems because it is flexible and better able to mirror the complexities of empirical reality.

A qualitative systems macro-model, a necessary first step in developing a workable analytical framework, was developed to guide the description and analysis of technology systems (see Figure 1). The macro-model is made up of four primary subsystems, plus the linkages that join them together (Swanson 1987: 2-4). The four subsystems are government policy vis-à-vis the technology system, technology development, technology transfer (here shown divided into both knowledge and input transfer), and technology utilization. Each subsystem can be modelled as a separate, holistic system (see Swanson 1987: 4).

The refinement of the analytical framework, with its associated methodological tools and subsystem flow analyses, has been an iterative, inductive process, with inputs based on extensive literature review, the service of consultants, and the insights and contributions of the original research team, as well as subsequent multidisciplinary case study teams. The macro-model was used to generate a set of indicators to be used as tools in the analysis of national technology systems. Four case studies of national agricultural technology systems were used as sources of empirical data. Case study countries include Ecuador (Peterson et al. 1988), Malawi (Swanson et al. 1986), Mexico (Peterson et al. 1987), and Taiwan (Johnson et al. 1987). Each case study resulted in further refinement of the analytical instrument through application to existing national technology systems. The original set of 47 indicators has been reduced by repeated application and evaluation of case studies to 18 indicators and 36 related measures.

Measures for the indicators were pulled from the literature or developed by the research team. A full examination of the analytical instrument, concentrating on a reduced set of indicators and their measures, was completed in 1987 (Sands 1988). The study combined a substantial review of the literature with an analysis of three case studies. The purpose was to describe and evaluate the indicators remaining at that point in time, along with their measures. Subsequently, a comparative analysis of the indicators and measures across four case studies has resulted in the selection of those measures judged to be the most effective for each indicator, as presented in the section on indicators and measures, below.

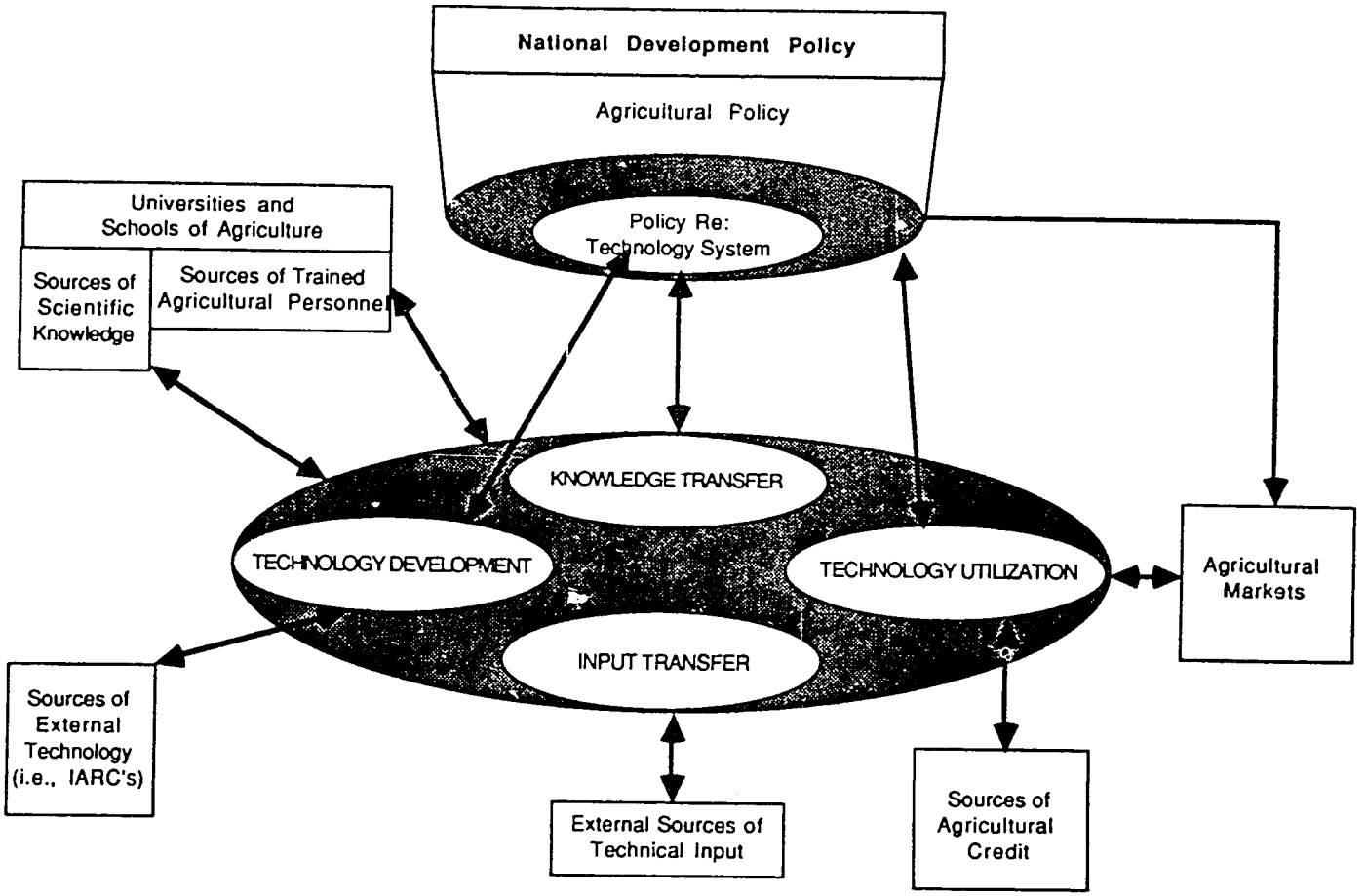

Figure 1. Macro-system model of a national agricultural technology system showing internal components and external factors

Individual indicators and measures are the means used to gather data; they are "tools of discovery" as Deutsch (1980: 11-12) phrases it. No individual indicator or measure is diagnostic in isolation, but the sum of indicators provides a strikingly useful overview of the system being analyzed.

The instrument that has evolved is a descriptive and analytical tool with two basic parts. The first is a set of methodological tools, including indicators with their measures and a brief farmer survey, which serve to organize data collection, to order data for comparison between countries, or to provide the basis for diagnosis of existing systems. As an inductive methodology, the indicators require and allow for adaptation to the realities of country contexts. The farmer survey, which is not described here, functions as a source of information, particularly on utilization, which contrasts with information acquired from government sources (e.g., Uquillas et al. 1988). The survey also provides a means of early identification of problem areas in the technology generation and delivery system from a farmer perspective. Farmer information is necessary to provide a check on perspectives from within government departments.

The second part of the analytical instrument consists of flow-system analyses of subsystems in the technology development and transfer system. The flow-system models that result from these analyses are unique to each national system. Essentially, it is a process of mapping the institutions and functional linkages that make up the system to determine how improved technology flows through to farmers. This mapping is accomplished by actually tracking different types of technology through the system, from researchers to farmers. Flow analysis depicts the functional arrangements of the different institutions in the system, including the primary linkages, key decision points, and time lags for different types of technology.

New technology is generally a package of different technological components, including such things as improved varieties, purchased inputs, and technical knowledge. Therefore, there are multiple paths by which a new technology or different technological components reach farmers. In addition, these multiple paths may differ, to a greater or lesser degree, between commodities. However, given the approach being employed in this methodology, a more generalized flow-system model can usually be derived for each major subsystem in the larger technology system.

Initially, seven different types of technology were to be tracked in this flow analysis. However, because of the complexity of the task, the relative importance of different categories of technology, and efficiency considerations, the list was narrowed to three main types of technology. These categories are (1) genetic technology, such as new crop varieties or hybrids, (2) agricultural chemicals, such as new pesticides, and (3) new cultural or

management practices, such as plant population, date of planting, and fertilizer usage.

Each flow-system model is an abstraction that reflects the actual operation of a country's agricultural technology subsystems, as opposed to the formal organigrams that depict the organizational structure as presented by government sources. It is the end product of applying the analytical instrument in the sense that each flow model is specific to the system or subsystem being analyzed and that each flow model identifies the primary institutional or linkage constraints to the development and flow of technology to farmers. An accurate grasp of the flow of technology through the entire system rarely exists among personnel within the national system.

The purpose of this paper is fourfold: (1) to summarize and display the Analytical Framework, (2) to reduce the number of measures to a manageable and effective methodological set for use in the analysis of agricultural technology systems, (3) to provide examples of how the indicators and their measures are used, and (4) to discuss and provide examples of flow-system analysis in the context of country case studies. The following pages are organized into three parts: a section that examines the indicators and measures, a section that examines the flow-system analysis with its application in the case studies, and a final discussion section.

The Methodological Tools: Indicators and Their Measures

The number of indicators included in the methodology was reduced to 15, with 71 measures, during the Sands' study. These were further evaluated, and 18 indicators with 37 measures have been included in this paper. Based on empirical tests in the four case study countries, these appear to be sufficient to examine and describe agricultural technology systems in most countries.[2] Fundamental questions guiding this examination are the following: What indicators and measures appear to be most effective and efficient in describing and measuring an agricultural technology system? Which indicators and measures appear to be operational in the field?

A measure was considered effective if (a) it was useful both in the case studies and in the literature, or (b) it was judged to be potentially useful for diagnosis. Use in the case studies was an indication that the measure was operational in the field. Multiple use in the literature indicated that there was some consensus on the importance of specific indicators and measures. Since no two national technology systems are alike, alternative measures

[2] The framework has not been tested against centrally planned economies.

for the same indicator are sometimes necessary. The nature and form of national data available in individual case study countries dictated to a large extent the measures actually used.

The more useful measures found in the case studies and in the literature are presented in this paper for each indicator.[3] The selection represents the judgment of researchers involved in the case studies. Unless otherwise indicated, the measures included in the paper were used in both the literature and the case studies, based on the literature review carried out by Sands (1988).

Indicators and Measures of Public Policy

The realm of public policy guides the direction of agricultural development by establishing courses of action and goals at the national level. Priorities are set, resources are allocated, and rules are elaborated which create the environment by which technological progress is made or restricted.

Indicator 1: Government's Financial Commitment to Agriculture

This indicator has significance because it shows how important the government considers agriculture in relation to other sectors of the economy. A number of sources emphasize the importance of assessing public expenditures on agriculture (e.g., Cox 1984; Elias 1981; FAO 1984). A single measure was more effective than the others.

1. The measure shows the average annual rate of total public spending on agriculture over a specific period for a country or for a group of countries. If data are shown in time series, as in Table 1 below, the information provides trends that identify the degree and consistency of support for the agricultural sector by the government. In Ecuador, for example, it was found that the government investment in agriculture was 4% of total government expenditures in 1985, down from 7.1% in 1981 (Peterson et al. 1988: 28). Similar data from Mexico indicated that the average annual rate of agricultural expenditures was 9.5% of total expenditures between 1977 and 1982 (Peterson et al. 1987: 30). In Malawi, agriculture's share of total recurrent public expenditures was 10.5% between 1980 and 1986 (Swanson et al. 1986: 16).

[3] Backup measures for use in data situations not encountered in the four case-study countries can be found in Sands (1988).

Table 1. Government Investment in Agriculture, Ecuador (1981 to 1985)

	1981	1982	1983	1984	1985
	-------millions of 1975 sucres, rounded-------				
Total Gov. Budget	24,560	24,195	20,415	20,983	20,441
Agric. Sector Budget	1,735	1,662	1,426	917	826
Ag. Ex./ Gov. Ex.	7%	7%	7%	4%	4%

Note: Average Annual Expenditure on Ag., 1981-1985 = 5.9%
Source: Peterson et al. (1988: 28).

Indicator 2: Investment in Research and Extension

This indicator examines government expenditures on agricultural research and extension. In developing countries, the government usually provides the bulk of funding for the institutional components of the technology system, although donor funding may also be significant. Private-sector spending on technology development and transfer is usually insignificant until later in the development process. Adequate financial support for agricultural research and extension is advocated by many authors, including Janvry and Dethier (1985), Oram et al. (1979), Elias (1981, 1985), Evenson (1986), Oram and Bindlish (1984), etc. Three measures were found to be most effective.

1. The first of these measures gives the percentage of AGDP spent on agricultural research. Among the case studies, there was considerable variation in the percentage of AGDP spent on research: Mexico spent 0.42% in 1985, Ecuador spent 0.31% in 1986, Malawi spent 0.72% in 1985, and Taiwan spent 1.2% in 1985 (see Figure 2). The measure is commonly used; the World Bank (1981) suggests that 1% to 2% of AGDP be invested in research in less-developed countries to insure an adequate flow of technology.

2. The second measure examines public expenditure on research as a percentage of public investment in extension. This measure is recommended because it provides a means of examining the balance between expenditures in research and extension. It was used in the Ecuador case study where it was found that the research budget was approximately 22% of the extension budget in 1985.

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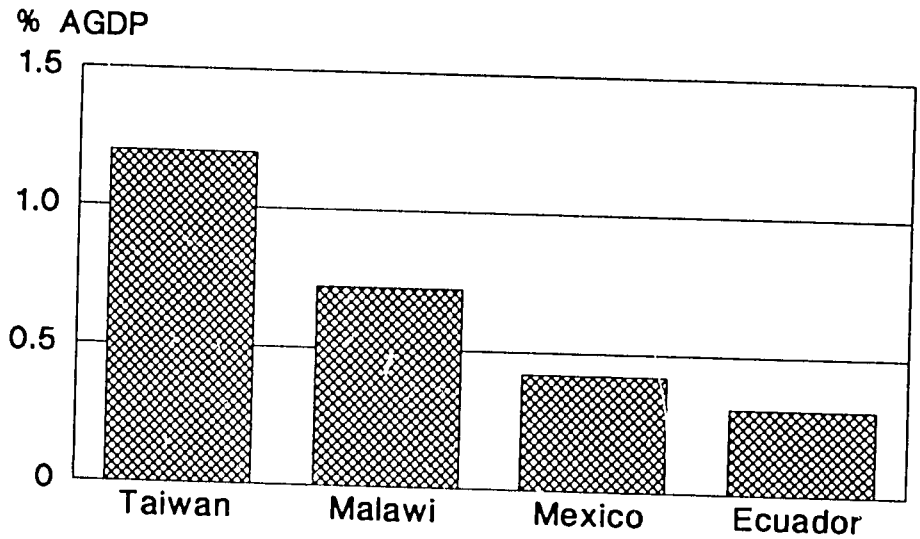

Figure 2. Percent of AGDP devoted to agricultural research

The general pattern is that high-income countries spend a higher percentage of AGDP on research, while low-income countries spend a higher percentage of AGDP on extension. The question of which is a more efficient strategy is an open one; Evenson (1986: 65-68) indicates that high investment in extension as opposed to research is a low-payoff strategy because of the low skill levels of extensionists in less-developed countries and because of difficulties with the transference of technology (due to the need for adaptation) from one country to another. The authors believe this perspective ignores the complementary set of private-sector institutions present in most high-income countries, contrasted with most lower-income countries. In higher-income countries, private industry has taken over a substantial amount of technology-transfer activity. In lower-income countries, where the private sector is not well developed, public-sector investment in extension may need to be higher if technology transfer is to occur.

3. The third measure is the percentage of AGDP spent on extension. It provides a measure of government investment in extension and knowledge transfer. Data for 1985 from the case studies shows that Malawi invested 2.2% of AGDP in extension, Ecuador invested 1.4%, and Taiwan invested 2.75% (see Figure 3). There are fewer empirical studies on public-sector investment in extension than on research, suggesting that this measure should be used wherever possible to develop more information on public-sector investment in extension.

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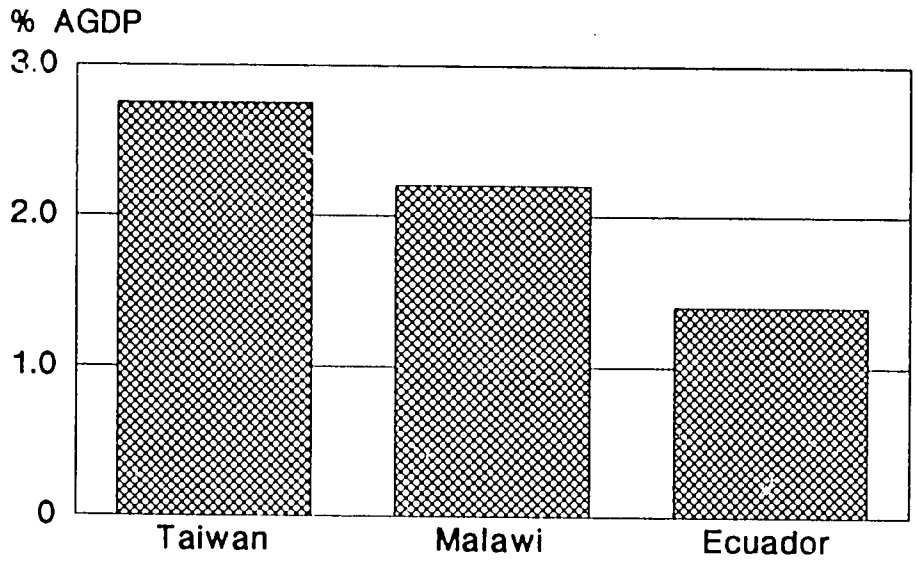

Figure 3. Percent of AGDP devoted to extension

Indicator 3: Availability and Utilization of Agricultural Credit

Agricultural technology is frequently embodied in purchased inputs such as seed, tools, agrochemicals, and fertilizer; therefore, access to credit can determine farmers' access to technology. These concerns with access to credit have often been discussed in the literature (e.g., Wortman and Cummings 1978; Mellor 1980; Pishke, Adams, and Donald 1983; Adams and Graham 1984; World Bank 1986. Two measures appear to be most effective for this indicator; however, case study experience found that data on credit are available in very divergent forms in different countries. Therefore, other useful measures for this indicator can be found in Sands (1988).

1. The first measure describes the percentage of short-term production credit available from institutional sources for the agricultural sector. It compares agricultural credit with total institutional credit. Access to complete data was clearly a problem in some case study countries. The example in Table 2 is from Malawi (Swanson et al. 1986: 35).

2. The second measure describes utilization of credit, providing information on where credit was used, by farm size category. This measure enables those studying equity issues to determine which groups of farmers receive agricultural credit. It is an important measure because it is one of the few indicators associated with the analytical framework that directly addresses equity issues. The example in Table 3 is from the Mexico case study (Peterson et al. 1987).

Table 2. Small-Holder Agricultural Credit Compared with Total Private Credit (1978 to 1984)

Year	Total Private Credit[1]	Small-Holder Ag. Credit[2]	Small-Holder Ag. Credit on Total
	millions of kwacha	*millions of kwacha*	%
1978	122.25	2.64	2.2
1979	170.75	2.63	1.5
1980	182.40	3.69	2.0
1981	191.79	5.82	3.0
1982	219.03	5.17	2.4
1983	254.69	8.55	3.4
1984	228.16	11.59	5.1

[1]Insitutional credit available to the private sector through rural-development projects.
[2]Excludes credit to estate farms.

Table 3. Producers Using Credit in Mexico, by Type of Farm

Type of Producer	Size of Unit	Units Using Credit
	hectares	%
Total		7.2
Campesinos		
Infrasubsistence	≤ 4	1.9
Subsistence	4-8	6.3
Stable	8-12	8.4
Surplus	12-25	11.2
Transitional Producers	no data	27.2
Commercial Producers	no data	67.2

Although specific data on farm size for transitional and commercial producers are not available. The fact that the campesino sector represents 87% of farm units indicates that larger producers receive most of the institutional credit. A similar pattern was found in the other case study countries, which has direct implications regarding the access of small farmers to improved agricultural technology in the form of purchased inputs. Small farmers do not have similar access to improved

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technology requiring cash outlay because most do not have access to credit.

Indicator 4: Pricing Policy

The next indicator of public policy addresses pricing policy. Price policies are set by government and are instrumental in creating incentives or disincentives for farmers to increase or decrease production. Discussions of pricing policy and its effects are common in the literature (e.g., Krishna 1967; Schultz 1978; Brown 1978; Timmer, Falcon, and Pearson 1983; Bale 1985; Cox 1984). Only two measures were found to examine this indicator. Both are recommended.

1. The first measure compares farm-gate to world market price for selected commodities. It addresses the gap between domestic (farm-gate) and world market prices by examining the incentive that exists for a farmer to produce a given crop. The assumption behind this measure is that crop production is likely to be encouraged if domestic crop prices are at or near world prices. Some countries pursue a cheap food price policy that effectively discourages farmers from adopting improved technology (especially purchased inputs). An opposite example from the Taiwan case study, as shown in Table 4, demonstrates a high degree of government intervention to stimulate the farming sector by providing farm-gate prices for farmers that are higher than world market prices.

Table 4. Farm-Gate, Domestic, and International Commodity Prices in Taiwan

Commodity	Farm-Gate	Domestic	International
	NT$/kg	*NT$/kg*	*NT$/kg*
Rice	14	20	6.5
Sugar	21	30	15.0
Corn	15	15	3.0

Source: Adapted from Johnson et al. (1987: 14).

2. The second measure examines pricing policy by comparing the farm-gate price of a staple food grain crop to the price of the same amount of fertilizer, generally nitrogen. The measure works on the assumption that farmers have an incentive to use fertilizer as long as a reasonable profit margin remains for any given crop. Although this measure did not rate as highly as the first, given the paucity of measures found for this indicator, the measure can be used if information is available. The use of this measure is illustrated in Table 5.

Table 5. Ratio of Price of Maize to Price of Fertilizer in Malawi (1980 to 1985)

Year	Average Cost of Fertilizer to Farmer	Official Starting Price of Maize	Ratio of Price of Maize to Price of Fertilizer[1]
	kwacha/kg	*kwacha/kg*	
1980/81	0.609	0.056	0.092
1981/82	0.707	0.056	0.079
1982/83	0.798	0.111	0.139
1983/84	0.906	0.122	0.135
1984/85	1.043	0.122	0.117

Source: Swanson et al. (1987: 29).
[1]Farmer's price of maize divided by average price/kg of fertilizer — as the ratio decreases, the profit to farmers also decreases.

The time series shows that the ratio of crop price to input price has been decreasing in recent years, leaving less profit margin for farmers.

Indicator 5: Farmer Participation in the Technology System

As Swanson (1987) points out, farmer participation in the technology system as well as direct involvement in government policy formulation is important to maintain the flow of resources to the technology system and to influence the priorities and programs of the system. The importance of farmer participation in development projects here has been recognized in the literature over the past decade (Cernea 1985; Chambers and Jiggins 1987; Uphoff 1981, 1982, 1985; Blencowe et al. 1981; de Janvry 1978; Morss et al. 1976, etc.). Some authorities (e.g., Uphoff 1981; Blencowe et al. 1981) have suggested that nonadoption of technology and failures of development projects are due, in part, to the lack of farmer involvement in problem diagnosis and project design.

The participation issue is complex: in some countries, large landowners control the mechanisms of farmer representation in the technology system. The result is that the demand for technology suitable to the needs of small farmers is seldom identified at the policy and programming levels of the system (de Janvry 1978; Peterson et al. 1988). The need for broad-based farmer representation revolves around the goal of more equitable distribution of benefits to all target groups in rural areas. This cannot occur without the representative participation of the major groups of farmers in the technology system.

The most useful proxy of assessing farmer participation is an examination of existing farmer organizations. A primary reason why small farmers are excluded from or left behind in the development process is their individual lack of power within the society. The formation of organizations can increase their social, political, and economic well-being (Morss et al. 1976: 254).

Few measures have been devised to objectively and accurately measure farmer participation in the technology system; in addition, in-country conditions often limit the acquisition of accurate data on farmer organizations. Two measures are presented below which provide a reasonable measure of farmer participation and organization.

1. The first measure, taken from Morss et al. (1976), addresses the viability of farmer organizations or the organization system in specific instances. It provides an index score that assesses farmer organizations. The index scores can be used to assess the efficiency of individual farmer organizations or to compare the relative efficiency of farmer organizations by country or project area. In Table 6, the measure is used to assess the viability of a national association of small farmers in Zimbabwe (National Farmers Association of Zimbabwe 1986).

Table 6. Viability of the National Farmers Association of Zimbabwe

1. Channels to the Outside	2
2. Extent of Organizational Activity	2
3. Representativeness	1
4. Continuity	1
Total Index Score	6

Code:

1. 2 = multiple channels to outside agencies, organizations, and individuals, which extend beyond the project and agencies sponsoring project; 1 = channels established to agencies supporting the project; 0 = insignificant outside channels.
2. 2 = multi-tiered network moving beyond local organizations to regional or national ones; 1 = single-tiered, financially sound organization at local level; 0 = neither of the above.
3. 1 = broad-based organization encompassing many small farmers, few restrictions; 0 = selectively based organization encompassing only a limited number of potentially eligible small farmers, with many restrictions.
4. 1 = local organization is a permanent local institution; 0 = local organization is a temporary local institution.

Source: Portion of a complex index on self-help taken from Morss et al. (1976: 255).

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The potential index score is 0 to 6. In the example above, Zimbabwe has the maximum score, indicating that this small-farmer organization is a highly viable system for farmer participation. The index can also be used to compare the relative efficiency of farmer organizations between geographical areas.

2. INTERPAKS researchers devised the second measure, portions of which were used in case studies by INTERPAKS; however, the lack of data in some countries limited its use. Table 7 is from the Ecuador case study.

   In the Ecuador case, a single farmer organization, Camaras de Agricultura, effectively controlled farmer representation within the national agricultural system. This participation included both commodity groups and the general farm organization from the local to the national level. Unfortunately, organizational mechanisms, such as invitational recruitment, membership fees, and requirements of land ownership severely limited small-holder membership. This effectively confines farmer organization and representation on government policy boards and program committees to large landholders. When the percentage of farmers belonging to any registered farmer group in Ecuador was

Table 7. Assessment of Camaras de Agricultura, Ecuador

1. Number of different farmer organizations operating	5
2. Level of policy participation in farmer organizations	5
3. Determination of membership in organization	0
4. Method of representation on policy and planning committees	1
5. Method of decision making within the organization/s	3
Index subtotal	14 x 10% = 1.4

The index subtotal is multiplied by the percentage of farmers belonging to any farm organization. The result is an index score with a possible range of 1 to 25. The individual items are coded as follows:

1. No farmer organizations = 0, 1 = 1, 2-3 = 2, 4-5 = 3, 6-10 = 4, 11 or more = 5
2. 0 = no participation; 1 = local or village-level participation; 2 = zone or parish participation; 3 = district participation; 4 = state or provincial participation; 5 = national participation.
3. 0 = membership determined by invitation; 3 = required by law; 5 = open to all types of farmers.
4. 0 = no representation on policy or planning committees; 1 = representatives from organization selected by government officials; 3 = representatives from organization selected by appointment from within the organization; 5 = representatives selected by open election by the organization's membership.
5. 0 = decisions made by chair; 3 = decisions made by subcommittee vote; 5 = important decisions made by vote of full membership.

computed, it was found that only 7% to 10% were members of an organized group; these members were primarily medium- and large-scale farmers. The representation of smaller farmers in these organizations was considered to be too low to have any effective input into the national technology system. Therefore, the low score of 1.4 of a possible 25 points reflects the lack of broad-based representation of farmers, especially small producers, in the technology system of Ecuador.

Indicators and Measures of Technology Development

The area of technology development is important because it is within this subsector of the analytical framework that new and improved technology is developed or adapted for use within a country or region. These indicators measure factors that affect the performance of the research subsystem.

Indicator 6: Access to External Knowledge and Technology

This indicator is important because access to externally developed technology can be an efficient means by which a country can borrow improved technology and then adapt it for home-country use. The advantage of adaptation is that new a technology can be modified and/or tested for possible dissemination to farmers in much less time and at less expense than would be involved in developing a new technology from the ground up. This advantage is particularly important for developing countries with less research capacity and urgent food production needs. By initiating and maintaining professional contacts with research institutes, such as the international agricultural research centers, the opportunities for discovering and borrowing suitable technology are considerably enhanced. These external linkages are widely discussed in the literature (e.g., Swanson 1977; World Bank 1981; Mosher 1982; Pinstrup-Andersen 1982; Ruttan 1982; Oram 1982); however, they are seldom measured. One measure developed by the research team has been found to be efficient for this indicator.

1. It is an aggregate measure that produces an index number enabling those assessing the technology system to determine the degree to which interaction with external researchers is taking place. The index number assesses three types of interaction between national commodity scientists and outside sources of agricultural technology. These interactions include exchange of genetic materials, training, and consultation. It was not found in any references. Table 8, which provides an example of its use, is taken from the Ecuador case study.

   Contact with the International Potato Center (CIP) is at a high level in Ecuador and the indicator shows an index of nine on a nine-point scale.

-8'

Table 8. Access to External Sources Available to Potato Researchers

Access to	Level of Access
Genetic Technology	3
IARC Training	3
Regular IARC Consultations	3

Source: Peterson et al. (1988: 70).
The scale is 0 to 3 for each type of access, with 3 representing the highest level of access.

Indicator 7: Human Resources for Agricultural Research

Human resources for agricultural research is the second indicator reviewed within the area of technology development. This indicator is important as it provides information about the availability of qualified research scientists and support technicians in a research system. Well-trained personnel are essential; an effective research program cannot be designed or executed without adequate human resources. The matter of human resources for research is abundantly covered in the literature (e.g., World Bank 1981; Mosher 1982; Oram 1981, 1983; Oram and Bindlish 1981; Elz 1984; Oppen and Ryan 1985).

1. The first measure examines support given to scientists in the form of technicians. It gives a ratio of scientists to technicians, where a 1:2 ratio

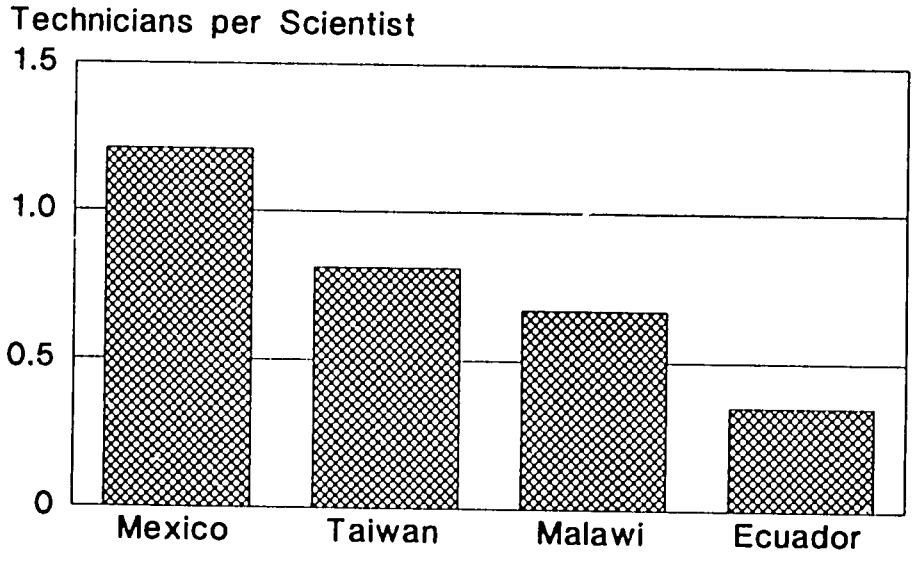

Figure 4. Ratio of technicians to research staff

is considered optimal in making the most efficient use of scarce scientists. The ratios for the four case studies are compared in Figure 4.

2. The second measure provides the number and percent of scientific personnel at different levels of training in a research system. Simple in nature, the information is essential if the human resource dimension of a technology system is to be described and evaluated. Particularly important is the proportion of researchers with postgraduate research training, especially doctoral-level training. Without this information, the technology-development subsystem cannot be adequately described and no judgment can be made as to whether or not human resources constitute a constraint in the system. Figure 5 compares percentages of PhD, Master's, and BSc degrees in each of the case studies.

3. The third measure examines the trend in research capacity of an agricultural research system by tracing changes in the number and quality of research personnel over time. Such information can determine if research capacity is increasing or decreasing in breadth and depth. The example in Table 9 is taken from the Mexico case study, which shows improvement over time.

Indicator 8: Resource Allocation to Research Salaries and Programs

There are often imbalances in the proportion of the research budget that goes for salaries as opposed to research programs and operations. If the

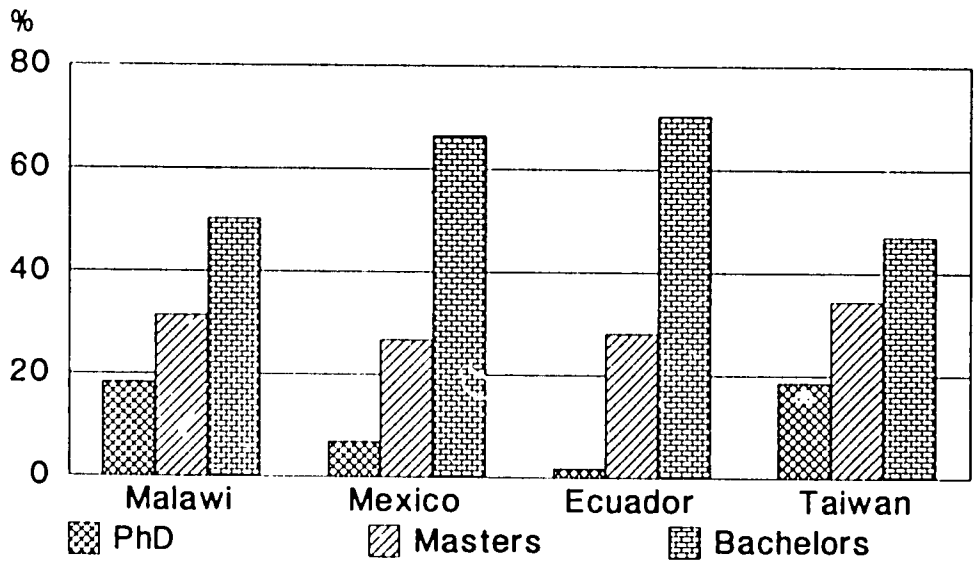

Figure 5. Percent of scientific staff by level of training

Table 9. Scientific Personnel in INIA, by Degree Level, 1980 to 1985

Year	PhD		Master's		Ingenlero Agronomo		Total	
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
1980	72	7.4	210	21.6	692	71.0	974	100
1981	79	7.9	231	23.0	696	69.2	1006	100
1982	81	7.5	246	22.7	752	69.5	1079	100
1983	84	7.8	269	24.9	729	67.4	1082	100
1984	97	8.0	305	25.0	818	67.0	1220	100
1985	104	8.7	328	27.5	761	63.8	1193	100

Source: Peterson et al. (1987).

imbalance becomes severe, financial allocations for research programs can become inadequate and, as a consequence, greatly reduce research output and system efficiency. This problem is frequently encountered in developing nations and can be considered a major constraint to a technology system The proportion should be examined in every national system. A major divergence from an investment of 40% to operations/programs and 60% to salaries may indicate a serious misallocation of resources. This problem is frequently discussed (e.g., Ruttan 1982; Daniels and Nestel 1981; Swanson 1987; Oram 1983; UNDP-FAO 1984), but measures of this indicator are seldom found in the literature. A single measure appears sufficient.

1. This measure is the percentage of the research budget allocated to research programs and operations, salaries, and capital investments. Since capital investments are often donor-financed, most attention is given to the allocation of recurrent resources between salary and program costs. The measure is most instructive if applied in time series. The trend in resource allocation over time is generally associated with research outputs but with a time-lag factor of years, depending on the type of research. These percentages are compared, using three case studies, in Figure 6.

Indicator 9: Resource Allocation to Commodities

This indicator is important in identifying imbalances in research focus or investment within a country's agricultural research system. Some countries invest a disproportionately large share of research resources in export/cash crops (as a result of colonial investment patterns or a need for foreign exchange) but too little in food crops. Human resources or budget amounts, or both, assigned to specific commodities can be used to identify the pattern for specific national systems. This concern has often been addressed in the

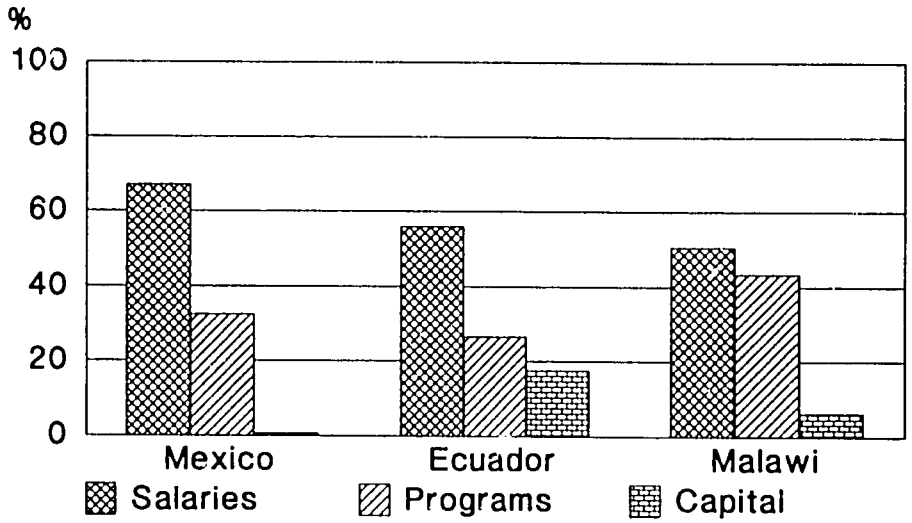

Figure 6. Allocation to salaries, programs, and capital in agricultural research

literature (e.g., Daniels and Nestel 1981; Oram and Bindlish 1981; Pinstrup-Andersen 1982; Idachaba 1980; Oram 1983). There are a variety of measures reported in the literature (Sands 1988); the ones listed below were judged most effective in the case studies.

1. The first measure uses financial investment in agricultural research by commodity program or by crop, compared to the commodity's contribution to AGDP. It can be used in time series and was commonly mentioned in the references. The following example (see Table 10) from Malawi is taken from Swanson et al. (1987: 23).

   There appears to be an overinvestment in some crops (e.g., coffee) and an underinvestment in important food crops (e.g., roots, tubers, maize).

2. The second measure also uses an index value based on the percentage of research personnel or research activity associated with each commodity research program, compared to each commodity's contribution to AGDP (in percent). Again, the measure allows a commodity's AGDP value to be compared to its importance in the national research system. This measure was designed by the research team. The following example examines research activity from the Ecuador case study (Peterson et al. 1988: 68).

   An optimal investment level depends on a number of factors, but a major divergence from an index of 1 raises allocation questions that should be

Table 10. Relative Contribution of Commodities to AGDP and Relative Level of Research Investment in Different Agricultural Commodities

Commodity Research	Contribution to AGDP[1]	Level of Research Investment[2]	Index of Investment[3]
	%	%	
Maize	21.4	7.1	0.3
Rice	1.1	3.0	2.7
Millet, Sorghum, & Wheat	0.5	3.3	6.6
Roots & Tubers	8.2	2.7	0.3
Groundnuts	8.1	5.7	0.7
Pulses & Oilseeds	1.2	3.3	2.8
Cotton	1.9	6.0	3.2
Tobacco	22.4	17.9	0.8
Tea	8.9	20.4	2.3
Coffee	0.5	3.3	6.6
Sugar	0.9	4.0	4.4
Fruits & Vegetables	12.8	10.6	0.8
Livestock	9.3	11.6	1.2
Firewood	2.7	1.1	0.4
Fish	0.1	n.a.[4]	n.a.
Total	100.0%	100.0%	

[1] Based on a 6-year average, 1981-86.
[2] Based on a 6-year average, 1980-85.
[3] Computed by dividing the level of research investment by the relative contribution of the commodity to the AGDP. An index number of less than 1 indicates a relatively low investment.
[4] *n.a.* = data not available.

examined further. Table 11 shows several areas of possible misallocation, most notably in barley and wheat and in soybean research.

Indicators and Measures of Technology Transfer

Indicators and measures associated with technology transfer provide information on various resources and activities associated with knowledge transfer from researchers to farmers. Six indicators of technology transfer are discussed here.

Indicator 10: Access to and Availability of Internal Technology

The first indicator, access to and availability of technology, is discussed in the literature (e.g., Nagel 1979; Rogers and Kincaid 1981; Mosher 1978; Lowdermilk 1981; Blanckenburg 1984; Johnson and Claar 1986), but few

Table 11. Index of Research Investment Based on Percent of Experiments and Trials by Commodity, Compared with the Economic Contribution of the Commodity to AGDP

Commodity	National Contribution to AGDP[1]	Experiments & Trials/Year[2]		Index of Research Investment
	%	No.	%	
Animal Production	36.2	44.2	5.3	0.1
Bananas	7.6	21.5	2.6	0.3
Rice	5.4	61.3	7.3	1.3
Cacao	5.3	34.0	4.0	0.7
Potato	4.9	27.2	3.4	0.7
Coffee	4.3	15.8	1.9	0.4
Corn	4.1	188.2	22.5	5.5
Soybeans	0.9	61.3	7.3	8.1
Barley and Wheat	0.7	127.0	15.3	21.8
Hunting and Fishing	10.3	n.a.[3]	n.a.	n.a.
Forest Products	12.8	n.a.	n.a.	n.a.
Other Ag. Products	12.8	253.6	3[illegible]	2.4
Total	100.0	834.2	100.0	

[1] Based on 6-year average, 1981-86.
[2] Based on 6-year average, 1980-85.
[3] *n.a.* = data not available.

empirical studies were found that attempted to measure the strength of the linkage between research and extension. This issue requires additional study. Several measures were used in the case studies; one appears most appropriate for field use.

1. This measure examines the nature and frequency of interaction between research and extension personnel. Extension must have formal and/or informal means of learning about new technology developed or adapted by research in order to organize educational/communication programs about the technology for farmers. The nature and extent of extension/research contact determines whether the flow of technology to farmers is adequate and appropriate. Each of the case studies addressed this measure in some fashion; the measure was not found in the literature. The example given in Table 12 is from the Malawi case study.

   The result of this measure is a qualitative view of the research-extension interface. In this instance, informants indicated a moderate level of

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Table 12. Informants' Estimates of Frequency and Level of Contact between Extension and Research

Types of Contact	Frequency	Level of Contact
Visits to research stations by appropriate transfer personnel	monthly	moderate
Joint on-farm trials/demonstrations conducted by research and transfer personnel	irregular	low
Technical publications received from research by transfer system	annual	moderate
Workshops/training sessions given by research on new technology	annual	moderate
Joint planning meetings between research and transfer personnel to develop technical recommendations	semi-annual	moderate

Source: Swanson et al. (1987: 39).

contact, with little in the area of joint on-farm trials and demonstrations. In the Ecuador case study, the same categories were used, but a scale of 0 to 3 measuring contact was used, with an average of 1, or a low level detected. This second alternative allows cross-country comparisons.

Indicator 11: Personnel Administration and Supervision

This indicator measures various aspects of personnel supervision, evaluation, and administration. This factor is viewed as important in the literature (e.g., Lele 1975; Ekpere 1974; Watts and Claar 1983; Vengroff 1984), but there is almost no use of this indicator or associated measures in the literature. A number of measures were employed in the case studies, two of which were judged to be more effective for the country case studies.

1. The first measure examines personnel evaluation and supervisory procedures to determine if they exist and, if so, which criteria are used. Lack of proper supervision and evaluation, including both positive and negative sanctions, is a weakness in some extension systems with direct implications for personnel performance. The management system for extension personnel should be examined to determine if this is a possible constraint. Table 13 provides an example of its use.

Table 13. Personnel Management Procedures Used in the Taiwan Extension System

Item	No	Yes
Evaluation Procedures		
Are there written and distributed evaluation procedures and criteria?		x
Is there an annual written evaluation on each staff member?		x
May different supervisory levels have input?		x
Are field assistants notified of evaluation results?		x
Does the procedure involve follow-up counseling or training when needed?		x
Supervision		
Is there a reasonable ratio of supervisors to field staff?		x
Are supervisors instructed to observe performance and provide counseling?		x
Do supervisors prepare written evaluations and discuss them with employees?		x
Positive Incentive Criteria		
Is pay distributed on a merit basis?		x
Does a considerable range in salary exist based solely on performance?		x
Does extra training result in higher pay for the same job?		x
Are promotions based on performance?		x
Are supervisors encouraged to recognize excellent work on the job?		x
Negative Sanction Criteria		
Does the system provide informal feedback on poor performance?		x
Does the system provide for written reprimands?		x
Does the system provide for punishment such as loss of pay or demotion?		x
Does the system dismiss employees for incompetence that cannot be corrected?		x

Source: Johnson et al. (1987).

As shown in Table 13, the Taiwan extension system uses over 90% of the recommended personnel management procedures; therefore, it was rated as "excellent" on this measure. This example is in stark contrast to personnel procedures used in other case study countries.

2. The second measure involves a comparative analysis of salaries and benefits for extension personnel, contrasted with the personal emoluments received by comparable groups in other institutions. This indicates the availability and strength of financial incentives for employees. The measure was not found in the references. The scaled measure used in Table 14 is from the Mexico case study. It also allows for cross-country comparisons (Peterson et al. 1987: 31).

The aggregated salary and benefit indicator for extension personnel in Mexico was computed to be 11, with potential scores ranging from 6 to 30, with 18 being average. A score of 11 is somewhat below average and indicates that extension may have a serious problem maintaining staff morale and performance.

Indicator 12: Time Allotted to Technology Transfer

The third technology-transfer indicator, time allotted to technology transfer, had only one important measure. The importance of concentrating on educational and related transfer activities is discussed in the literature (e.g., Stavis 1979; Benor et al. 1984; Sigman and Swanson 1984; Blanckenburg 1984; Claar et al. 1984). This measure addresses the amount of time extension field workers spend on extension or educational duties, contrasted

Table 14. Relative Level of Salary and Benefits for Extension Personnel in Mexico

	Relative Level of Salary & Benefits[1]	Absolute Level of Salary & Benefits[2]
Technical or subject-matter specialists (relative to research officers at experiment stations)	2	4
Field extension officers or agents (relative to secondary school teachers who live in villages)	2	1
Field extension assistants (relative to primary school teachers who live in villages)	1	1
Total	5	6

[1]Relative level: 1 = much lower than the comparison group; 2 = somewhat lower than the comparison group; 3 = about the same as the comparison group; 4 = somewhat higher; 5 = much higher than the comparison group

[2]Absolute level: 1 = a very poor standard of living (difficult to obtain the basics); 2 = a poor standard of living, but able to obtain sufficient food, clothing, and shelter; 3 = an average of living in comparison with other families in the community (the family is able to make ends meet); 4 = above-average standard of living in the community (upper 30% of the community); 5 = high standard of living relative to other families in the community (upper 10% in terms of income level).

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with nonextension duties. This is a serious problem in some extension systems in that field workers are required to undertake so many nonextension duties that their educational duties are neglected and/or their educational credibility is undermined. The following example from the Malawi

Table 15. Duties and Responsibilities of Extension Field Personnel in Malawi

Duties and Responsibilities	Number of workdays/year	Percent of time spent on activity
Nonknowledge-Transfer Activities		
Regulatory work (monitoring compliance with government directives & regulations)	0	0
Data collection (census, crop forecasting, etc.)	3	1
Work on other government programs (e.g., subsidies, credit, etc.)	46	18
Servicing local government (settling disputes, etc.)	0	0
Knowledge-Transfer Activities		
Planning and conducting on-farm extension visits	57	20
Planning and conducting educational meetings	108	43
Other educational activities	0	0
Planning and Support Activities		
Preparing administrative reports	12	5
Attending in-service training	30	11
Other support activities	4	2
Total	255	100%

Source: Swanson et al. (1987: 17).

case study (Table 15) shows that approximately 80% of the extensionist's time is spent on knowledge transfer and related activities. This measure allows for comparison between countries.

Indicator 13: Resource Allocation between Extension Salaries and Programs

This indicator examines the balance between personnel salaries and program costs. It should be used in time series and can signal emerging budget problems that will reduce program activities. The matter of resource allocation for personnel versus program costs has been discussed in some references, including Oram (1983), Boyce and Evenson (1975), and in the various

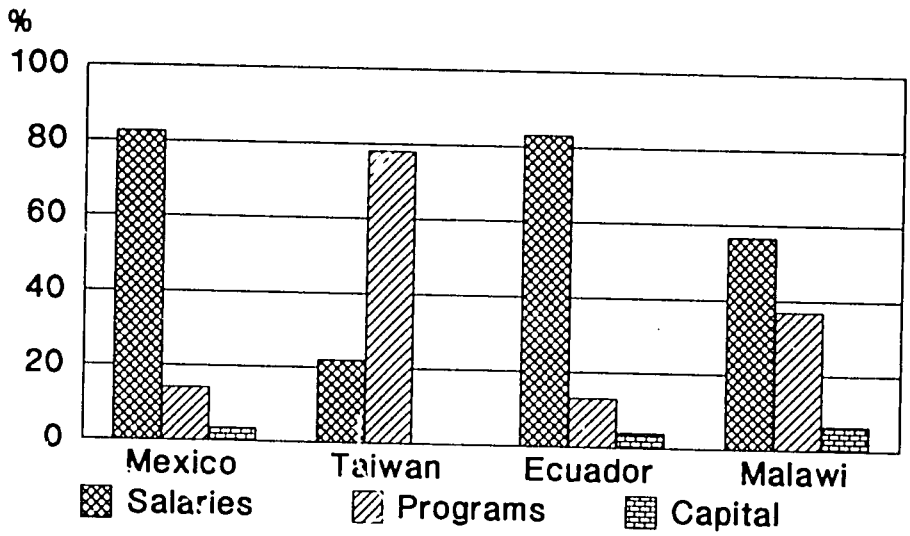

Figure 7. Allocation to salaries, programs, and capital in extension

country case studies. Essentially the same measure is used as for research in the first measure of indicator 7, above. Figure 7, which provides a comparison between the case study countries, shows considerable variation.

Indicator 14: Technology Dissemination

Technology dissemination is represented by many measures in the literature and in the case studies (Sands 1988). The unusual number of measures is due to the wide scope of activities addressed under the general rubric of technology dissemination. The measures examine extension activities occurring at the individual, group, and mass-media level, as well as the capacity of extension to produce its own teaching materials and farmer handouts. The ability of the clientele to utilize specific dissemination techniques is also measured, addressing such topics as radio ownership and the language understood or spoken by a radio audience. The realm of technology dissemination is widely discussed in the literature (e.g., Sands 1988; Blanckenburg 1984; Kang and Song 1984; Ekpere 1974). The following measures were judged most effective and efficient for an analysis of technology dissemination. The measures used should reflect the range of dissemination activities relevant to the project or area being analyzed.

1. The first measure is an average of the number of farm visits made annually by extension agents. The measure works best with extension strategies that emphasize individual contact methods; however, it does provide some measure of the level of individual farmer contacts per agent in any system. For example, in Mexico and Ecuador extension

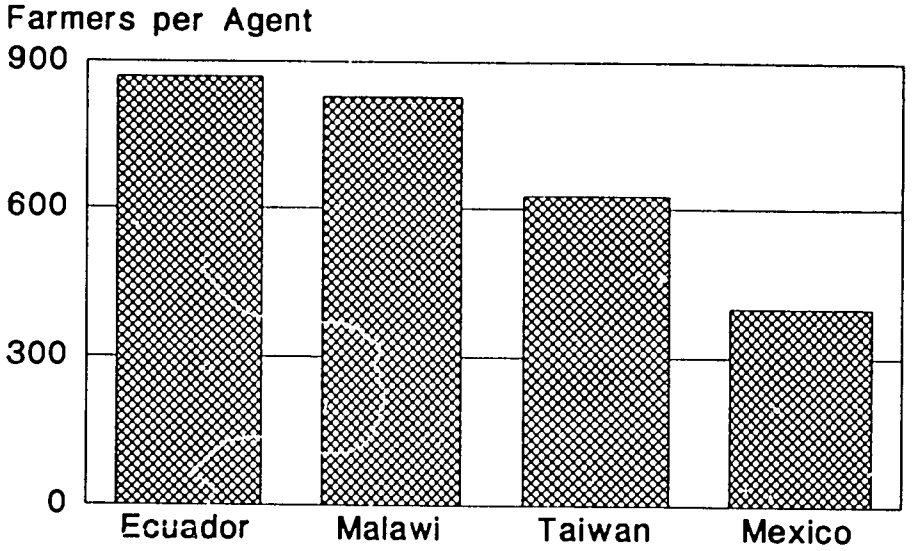

Figure 8. Ratio of extension agents to farmers

contact is primarily with organized groups of farmers, while in Malawi about 20% of contact time is directed to on-farm contact, resulting in 4% to 5% of farmers receiving individual visits at least annually.

2. The second measure is the average number of group meetings initiated by extension agents on an annual basis. This is important because it assesses one of the most efficient means of technology dissemination. The data can be used for comparisons between countries. For example, in Mexico the average number of group meetings was reported as 140 per agent per year, while in Malawi the average number is 108.

3. The third measure estimates the average number of "result" demonstrations conducted per agent on an annual basis. It is one of the most frequently mentioned measures in the literature and can be an excellent method of introducing new technology to the farmer. Although the measure is often found in the literature, case study experience suggests that these data may be difficult to obtain. Only the Mexico case study provided this information, where, on average, about four demonstrations are conducted each year by agents.

4. The fourth measure is the percentage of farmers or farm households who have direct contact with extension, either through individual visits, group meetings, field days or other avenues. Figure 9 provides cross-country comparisons for this measure.

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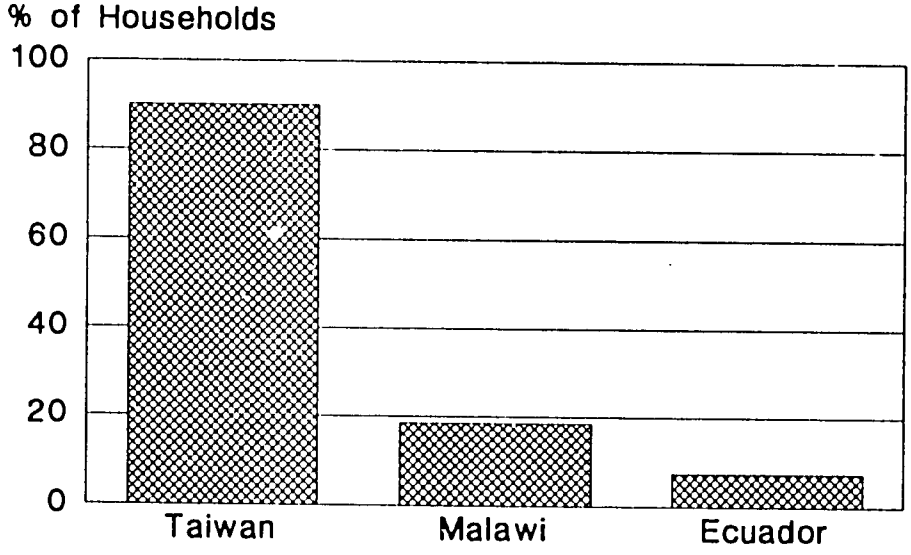

Figure 9. Extension contact with farm households

Table 16. Media Outputs from Extension Aids Branch, 1984 and 1985

New Extension Publications	6
Different Extension Posters (5,000 copies each)	5
Movies	4
Radio Programs	624

5. The fifth measure evaluates the capacity of extension to produce mass-media outputs and teaching materials. It is not mentioned in the literature but is judged to be essential for analyzing the capacity of extension to use varied channels of communication. The following example from Malawi (Table 16) illustrates a measure for media output (Swanson et al. 1987: 52).

6. The sixth measure estimates the percentage of households obtaining agricultural information from radio and the number of minutes per week that technical information is broadcast to farmers. Radio offers high potential in communicating to farmers and this measure allows an evaluation of the efficiency of using radio as a primary channel to reach farmers with new information. Comparative data for the case study countries is presented in Figure 10. Percentage of farm households with radios is taken as a proxy for households receiving agricultural information by radio.

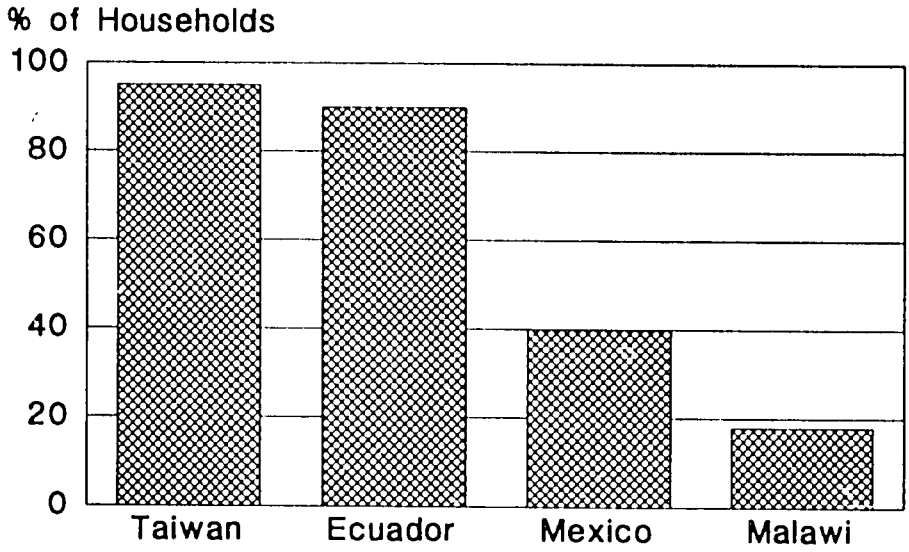

Figure 10. Farm households with radios

Indicator 15: Personnel Resources for Extension

This indicator measures one of the most important factors associated with technology transfer. Human resources are central to the process of disseminating information about agricultural technology from the researcher to the farmer and for reporting farmer feedback to researchers. The success or failure of an extension system depends, in large part, upon having an adequate number and mix of competent extension personnel. Personnel resources for extension are widely discussed in the literature (e.g., Whyte 1975; Coombs and Ahmed 1974; Orivel 1983; Claar and Benz 1984; Blanckenburg 1984; Benor, Harrison, and Baxter 1984; World Bank 1985).

1. The first measure is the ratio of agents to farm households, which was also used above as a measure for technology dissemination. Because these data are readily available, it is one of the measures used most widely in the literature to assess the capacity of an extension system to serve its clientele.

2. The second measure computes the number of subject-matter specialists (SMS) as a percentage of the total number of professional extension staff. It serves to assess the capacity of the extension service to provide technical backstopping and training for field personnel. Figure 11 compares SMS percentages for the case study countries.

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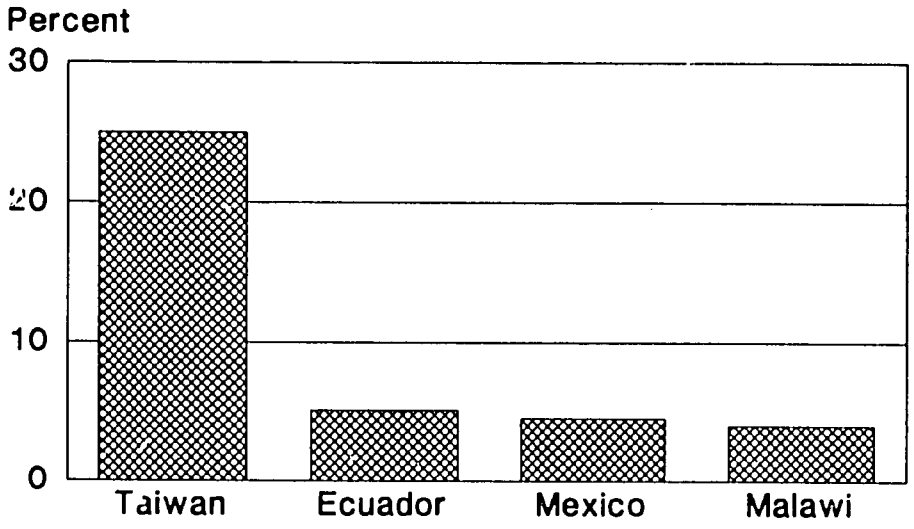

Figure 11. Subject-Matter Specialists to Professional Staff in Extension

The recommended proportion of SMSs under training-and-visit extension ranges from 12% to 15% (Benor, Harrison, and Baxter 1984). The average for Latin America is around 13%, and North American and European extension systems average around 18% to 20%.

3. The third measure tabulates staff qualifications by position and years of training, providing information on the quality of human resources available for extension programs. The use of this measure in the Ecuador case study is presented in Table 17 (Peterson et al. 1988: 98).

Technology Utilization

The fourth subsector addressed by this study was technology utilization. Indicators and measures associated with technology utilization dealt with two aspects, including adoption and use of improved technology, and access to and availability of physical inputs, such as seeds, fertilizer, and agrochemicals. Careful examination of this area is essential because utilization of new or improved technology is the primary objective toward which the entire technology system has been aimed. Three indicators are associated with this subsector.

Table 17. Educational Levels of Employees of the Ministry of Agriculture and Livestock, Ecuador, 1986-87

Educational Level	N.A.[1]	Director	Professional	Technical	Administrative	Service	Total	%
Postgrad	0	21	80	3	1	0	105	3.1
BSc Degree	2	36	714	37	45	2	836	24.7
Office Supervisor[1]	0	3	8	14	12	2	39	1.2
Some College	0	2	51	38	50	11	152	4.5
Voc. Sec. School	3	0	9	160	116	61	349	10.3
Secondary School	1	2	3	139	265	114	524	15.5
Less than Secondary School	6	0	8	50	90	1223	1377	40.7
Total	12	64	873	441	579	1413	3382	

[1]Not ascertained.

Indicator 16: Technology Adoption

Adoption and use of improved technology is a central issue in the literature (e.g., Pinstrup-Andersen 1982; Harris 1972; Shingi, Fliegel, and Kivlin 1981; Rogers 1983; Ashby 1982; Feder, Just, and Zilberman 1985). Two measures of adoption were considered most efficient for this indicator.

1. The percentage of farmers using a new technology is examined by this measure. The purpose of this measure is to determine the degree to which a recommended new technology has been adopted. Several types of new or improved technologies are usually examined. The example given in Table 18 is from the Malawi case study (Swanson et al. 1986).

2. The second measure examines the general level of technology adoption. It looks at the general use of improved technology, such as the amount of fertilizer used per hectare of cultivated land or the percentage of

Table 18. Adoption of Recommended Maize Technology in Malawi

Recommendation	Adoption
	%
Maize Plots in Hybrids	3.5
Maize Plots in Pure Stands	73
Early Planting	79
Weeding More Than Once	40
Maize Plots Fertilized	26
Maize Plots Fertilized Twice	5

Table 19. Use of Improved Seed and Fertilizer, by Producer Type

Producer Type	Use of Improved Seed	Use of Fertilizer
	%	%
Country Total	11.9	24.5
Campesinos		
Infrastructure	4.7	18.1
Subsistence	10.7	18.8
Stable	14.8	22.8
Surplus	22.6	31.3
Transitional Producers	29.2	48.3
Commercial Farmers		
Small	43.7	65.8
Medium	51.0	73.3
Large	59.3	82.6

Source: Peterson et al. (1987).

farmers using improved varieties. It can be expanded to include information on farm size categories. The example from the Mexico case study (Table 19) compares the percentage of farmers using improved seed and fertilizer by type of producer. Percentages refer to each subtype.

The producer typology for Mexico uses amount of land owned to define the Campesino categories and the number of laborers employed to define the Transitional and Commercial Producers. In this and other case studies, there is a strong correlation between farmer resources (land and labor) and rates of technology adoption.

Indicator 17: Access to Technology

Utilization of technology is dependent upon access to technology. The matter of access to technology has been addressed in the literature (e.g., Morss et al. 1976; Feder et al. 1985; Berry and Cline 1979; Mosher 1976; Pinstrup-Andersen 1982; Chitere and Dorne 1985; Kishore 1986). This indicator examines physical access to inputs by farm household. One measure was judged to be adequate for this indicator, although others are available in Sands (1988).

1. This measure provides an estimate of the average distance between farm households and input supply points, or the relative density of input supply outlets. Ease of access by the farmer to inputs has a direct

Table 20. Farmer Proximity to Agricultural Development and Marketing Corporation Supply Outlets or Depots, Malawi

Number of Depots	Farm Households per Facility	Cropped Hectares per Facility	Proximity to Facilities (%)	
			< 2 km	> 8 km
1,274	788	838	17.6	23.4

bearing on utilization. The example in Table 20 is adapted from the Malawi case study (Swanson et al. 1987: 16). Data for this measure are difficult to obtain in some countries.

Indicator 18: Availability of Technology

This indicator is important in that it examines whether or not agricultural technology is present to be utilized. Mosher (1976), Oram and Bindlish (1981), Pinstrup-Andersen (1982), and Kishore (1986), among others, have discussed the implications of availability of technology. The supply of inputs available in a country is examined, as well as farmer knowledge about recommended practices. Knowledge about input availability is essential when assessing a technology system; information should be gathered on both supply and knowledge. The following measure was considered to be effective for this indicator.

1. This measure estimates the supply of physical inputs over time. For example, recommendations on fertilizer usage cannot be followed unless an adequate supply of fertilizer is available. A first example from the Malawi case study is given in Table 21 (Swanson et al. 1987).

   The measure establishes trends in input availability by determining the change in input supply or sales over time. It indicates whether input availability or supply is worsening or improving. The measure was not

Table 21. Estimates of Fertilizer Supply and Usage on Small-Holder and Estate Land

Year	Smallholder Sector	Estate Sector
	kg/ha	*kg/ha*
1970	11.7	42.9
1975	13.7	75.8
1980	36.9	64.6
1984	50.3	140.2

Table 22. Import, Production, and Consumption of Improved Seed in Mexico

Year	Imported	Produced	Consumed	Utilized
	- - - - - - - *millions of 1977 pesos* - - - - - - -			%
1976	261	2299	2505	90.6
1977	335	2005	2245	89.3
1978	445	3089	3445	89.7

found in the literature. A second example of this measure, as shown in Table 22, is taken from the Mexico case study (Peterson et al. 1987).

The utilization of improved seed appears stable at about 90%; however, in-country production seems unstable. Overall consumption of seed has increased 37.5% over the three-year span for the country as a whole. Data for this measure come in different forms, and cross-country comparisons are difficult.

2. The second measure examines the degree of farmer knowledge about recommended practices. This information is difficult to obtain without a farmer survey or agricultural census, but it is important in isolating common constraints, such as lack of farmer knowledge about recommended practices due to the lack of an effective extension system. Information on this measure was gathered for the Ecuador case study in a brief farmer survey of potato growing areas, but estimates of farmer knowledge and use for the entire country could not be made.[4] Therefore, the example given in Table 23 was taken from a source quoted in Sands (1988: 255).

Table 23. Knowledge and Use of Recommended Agricultural Practices by Farmers in Nigeria and Mexico, 1961 to 1966

Country	Fertilizer Known	Fertilizer Used	Improved Maize Known	Improved Maize Used	Insecticide Known	Insecticide Used
	%		%		%	
Nigeria	79	39	70	32	38	33
Mexico	90	71.7	93.3	78.3	88.3	35

[4] The survey was conducted in the major potato-growing areas of the Sierra only, and a random sample of farmers was not obtained.

The Flow-System Analysis

The following sections provide real-life examples of how the flow-system analysis was applied to each category of technology. The examples presented here are taken from two of the INTERPAKS case studies: Ecuador and Malawi. In addition, since the same approach can be used to simulate alternative solutions to identified problems, a fourth figure is included from a third country to show how a new institutional capacity might be linked into the existing system. This simulation example focuses on one specific problem — a weak linkage between research and extension — and depicts one of several possible solutions.

As will be demonstrated by these examples, the flow-system model is a versatile tool in that it can be effectively applied across different types of technology systems, at different levels of analysis, and for both constraint analysis and simulation of alternative solutions. In the examples that follow, only specific constraints are identified and discussed briefly. The reader is referred to the full case studies for a more detailed analysis of the overall national system, including a fuller explanation of each flow-system model.

Genetic Technology

The first example is from Ecuador, where the case study gave special emphasis to potato technology. The particular concern that stimulated this study was that potato technology was not moving downstream to farmers. Therefore, a primary objective of the analysis was to diagnose the primary constraints limiting the flow of potato technology as the basis for planning an intervention to solve these problems. A number of constraints were identified, but here only the potato seed system is analyzed.

Genetic technology for potatoes can be broken down into two subcategories: new varieties and "clean" or virus-free seed. New potato varieties are developed through a plant breeding program where various characteristics for agronomic qualities, pest-resistance, and tuber quality are combined through well-established techniques of plant breeding and selection.

In recent years, the plant breeding program of the national research system (INIAP — Instituto Nacional de Investigaciones Agroprecaurias) has made extensive use of improved lines from the International Potato Center (CIP), both in screening advanced lines and for use in INIAP's breeding program. Since 1972, five new varieties have been released, but the dissemination and use of these new varieties has been very slow. Figure 12 is a flow-system model of the system of genetic technology for potatoes in Ecuador. Due to space limitations, the entire seed system is not explained here, only the identified constraints are briefly described.

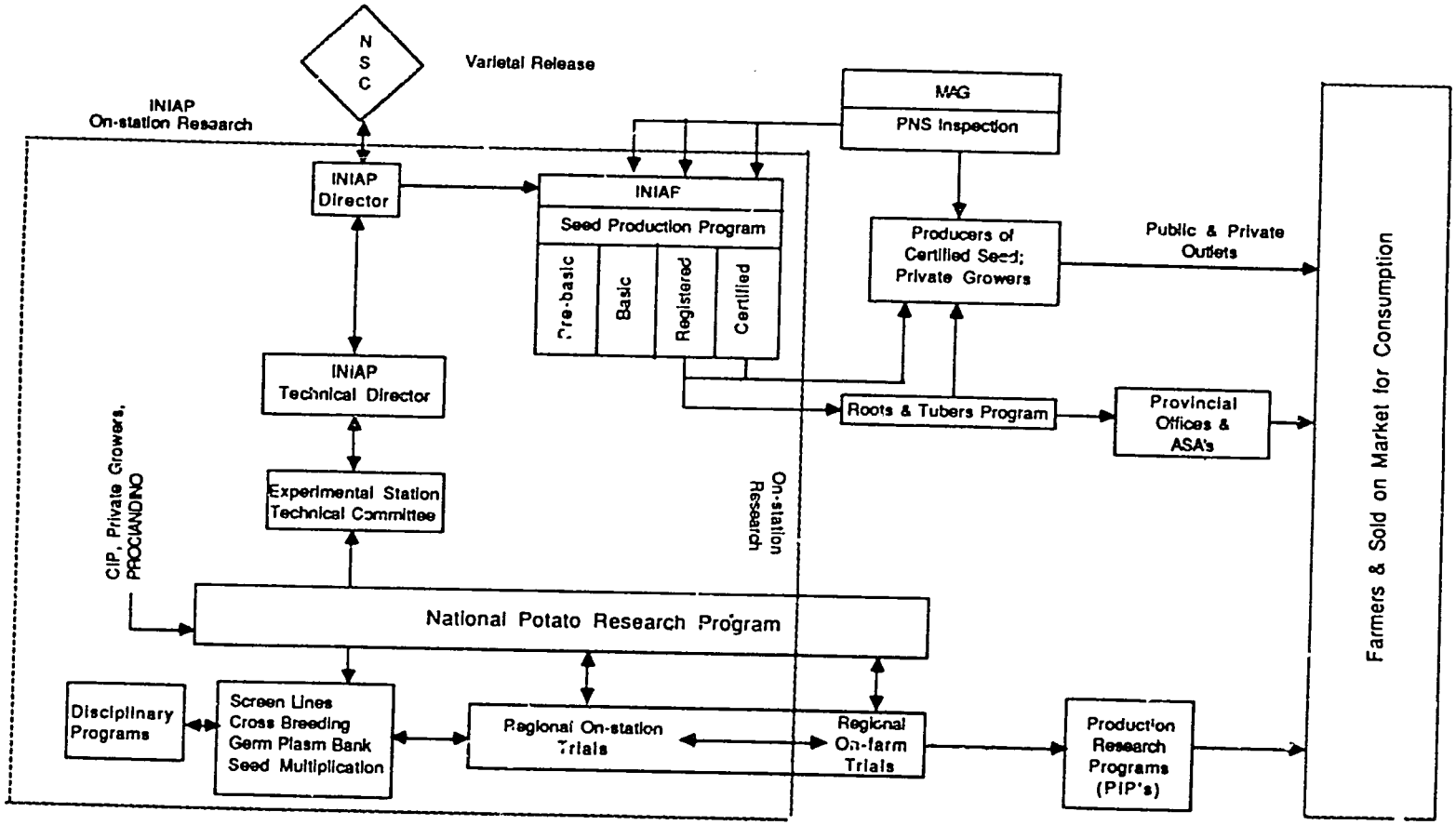

Figure 12.
Development and flow of genetic technology in potatoes to farmers (new varieties and clean seed)

For most crop varieties in Ecuador, certified seed production is handled by the national seed production agency (Empresa Mixta de Semillas, or EMSemillas) or by private seed companies. Because of the higher risk associated with producing certified potato seed (uncertain market demand, cost of production, distribution, and price), neither EMSemillas or the private companies are producing certified potato seed. Therefore, the Ministry of Agriculture and Livestock's (MAG) Technical Directorate for Roots and Tubers, and the Programa Nacional de Semillias (PNS) as well as INIAP's potato seed production program have worked together to increase the production of certified seed. These agencies have supplied registered seed to selected farmers for multiplication.

In 1986, 53 producers multiplied INIAP-registered potato seed to produce certified seed. However, the lack of an organized seed-distribution system has resulted in the majority of this certified seed being sold on the open market to consumers as cooking potatoes. The result is that most producers, especially small farmers, do not have access to certified seed, especially the new improved varieties. The same problem affects farmers' access to the virus-free replacement seed that is needed every three to five years as farmer-selected potato seed degenerates. Therefore, while it is estimated that nearly 19,000 tons of certified (clean) seed is needed annually, less than 5% of this amount is actually available to and used by farmers, with most of this small percentage going to large commercial farmers.

An important reason why INIAP has not expanded certified-seed production is that the income from the sale of both registered and certified seed is now deducted from INIAP's annual appropriation from the national treasury. Therefore, rather than these seed sales being an additional source of funds to expand the production of registered and certified seed or to fund additional potato research, this income directly reduces INIAP's overall research budget. This current arrangement is a clear disincentive for INIAP to increase the output of registered and certified seed. In fact, INIAP's production of registered and certified seed declined sharply in 1986 and 1987.

Chemical Technology

The second example deals with the agrochemical system in Malawi. Malawi has both an estate sector, where individual farmers privately own parcels of land (20% of land holdings), and a small-holder sector, where land is communally owned. However, access to agrochemicals differs sharply. First, there are few restrictions as to which agricultural chemicals may be imported into the country. Therefore, the estate sector has relatively easy access to new chemicals if there is a company representative in the country to import them, or if the estates are large enough to import the chemicals themselves. The factors determining the availability and use of

agrochemicals in the estate sector are essentially information and capital. Farmers must know how to use chemicals and have the resources to import or purchase them locally.

In small-holder agriculture, access to new agricultural chemicals is possible only after a lengthy testing program by the Department of Agricultural Research (DAR). Then eventual retail distribution can occur through the Agricultural Development and Marketing Corporation (ADMARC) stores. To be approved by the ministry for sale through ADMARC, a pesticide must be tested for a minimum of three years to determine the yield response and economic benefit to farmers. However, chemical companies must take the initiative for getting the material imported and transmitted to the DAR for testing. Therefore, the chemical company must supply the chemical to the DAR for three or more years of testing before a recommendation for approval can be sent forward to the Technical Recommendations Committee. In fact, the procedure (outlined in Figure 13) generally takes much longer.

One problem that was identified in this flow analysis is the issue of research or technology ownership. Since most chemicals are clearly a company product, the DAR takes a passive posture toward them. Therefore, rather than trying to actively screen all new types of chemical technology that are available worldwide (in terms of economic benefits as well as potential toxicity) and trying to approve the most effective materials for use by farmers, the DAR moves slowly and cautiously to extensively test each chemical received to limit institutional liability and professional vulnerability. In effect, the DAR is in a "no-win" situation since it cannot take credit for developing new chemical pesticides, but it can be blamed for allowing toxic products to be marketed. The result can be a very long period of testing (i.e., nine to 10 years) with no built-in procedures to move the process forward expeditiously (e.g., a decision in three or four years). The constraint occurs because DAR researchers function in a largely regulatory, rather than a research role.

A second problem is the negative perception of agricultural chemicals. Some pesticides can be quite toxic and can result in long-term health and environmental hazards. Since chemical companies are particularly sensitive and vulnerable to public criticism for polluting the environment, new-generation chemicals tend to be much safer, both for users and the environment, and tend to be more effective than the older materials. However, in many countries, including Malawi, older-generation materials are still being recommended and used, while the new materials are having difficulty getting through the system.

One of several examples of these excessive delays involves a new-generation insecticide that is very effective in controlling insects on cotton. Testing of

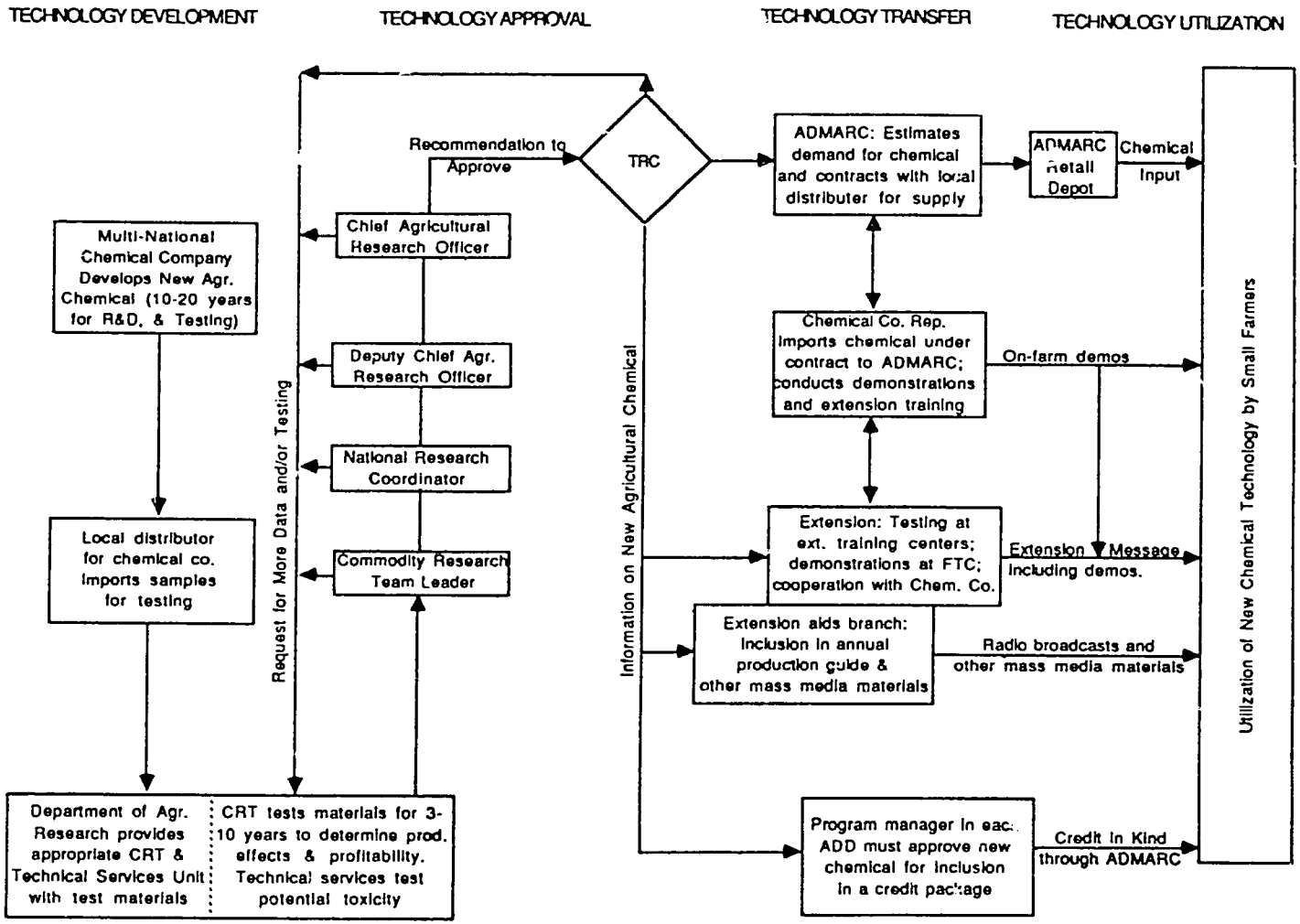

Figure 13. Flow of chemical technology to farmers in Malawi

this chemical started in 1975-76 in Malawi, but approval was delayed until 1984-85 by the Technical Recommendations Committee (TRC) for use in the 1985-86 season. Even though this chemical is widely used throughout Southern and Eastern Africa (i.e., Tanzania, Zambia, and Zimbabwe) and is recommended in nearly every major cotton growing country of the world, it has been very slow to reach small farmers in Malawi. After it was approved for the 1985-86 season, small farmers in Malawi still did not have access to this insecticide because of further delays in getting it approved for credit sales in each district. Instead, small farmers in Malawi handled 345 metric tons of the toxic pesticide DDT (in combination with another insecticide), which was still sold by ADMARC as the only pesticide available and approved for credit for controlling insects on cotton. Therefore, the new-generation chemical, which is more effective, safer to use, and costs about 60% less, was still unavailable to small farmers. Ironically, the company that supplied the DDT to ADMARC is the same company that manufactures the new-generation insecticide.

Cultural or Management Practices

The third example of flow-system analysis is also taken from the Malawi case study. It shows how a new institutional mechanism is being developed to produce location-specific technologies, although research policies have not yet been adjusted to reflect these institutional changes.

The previous approach used to generate a package of practices for new crop varieties or hybrids in Malawi was to work out the individual parts of the package through on-station experiments and trials. Subsequently, these individual components would be tested for three or more years in replicated field trials throughout Malawi. When one or more of these cultural practices had been fully refined and tested by a commodity research team, the recommendation would be sent forward, through the national research coordinator and chief agricultural research officer and his deputy, to the (TRC) for official approval (see Figure 14).

Once the cultural practice had been approved by the TRC, this new information moved through two channels of the transfer system. First, it movedss through mass-media channels, particularly printed materials and radio programs developed by the Extension Aids Branch. It was also included in the Annual Production Guide and released publicly through this channel. Finally, extension personnel received training and experience with the new practice at the extension training centers, before it was demonstrated to farmers. Demonstrations occurred first at the extension training centers and later in farmers' fields.

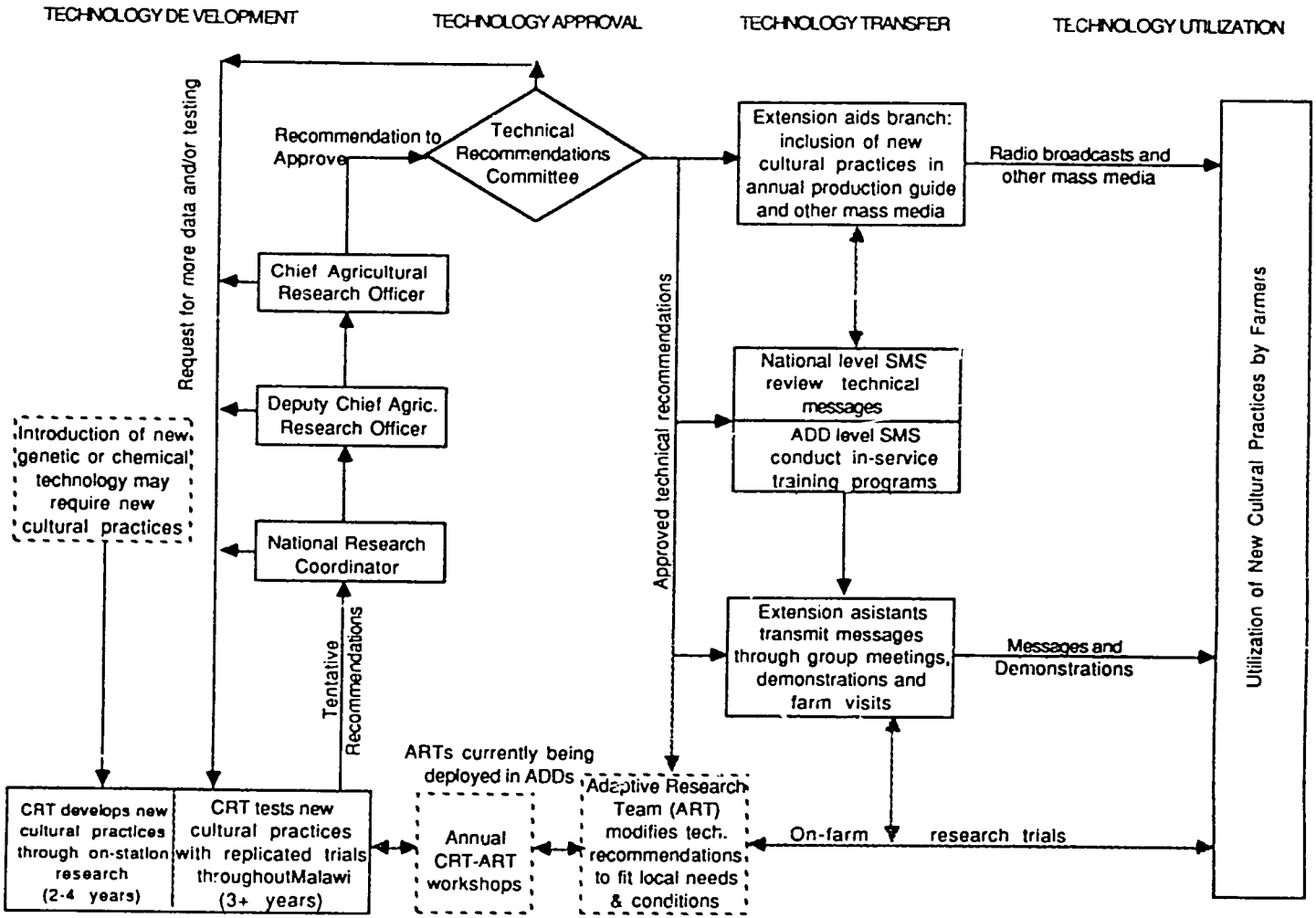

Figure 14. Flow of new cultural practices to farmers in Malawi

Since Malawi has three major agroecological regions, this centralized approach to technology development was unable to generate *location-specific* technology. Therefore, recommendations in the annual production guide and subsequent circulars generally specified a range of treatments (e.g., 60 kg to 80 kg of N and 30 kg to 40 kg of P per hectare) for each crop.

To develop more location-specific recommendations for farmers and to link more effectively with extension through its specialist staff, adaptive research teams (ARTs) were established and deployed to each of the eight agricultural development districts (ADD). This change implies that technical recommendations will be modified to reflect the specific agroecological and, possibly, socioeconomic conditions of each ADD. However, at the time of the case study, the chief agricultural research officer was still insisting that the TRC approve all recommendations and that ADD-level data not be given to extension. Therefore, national policy regarding the approval process for new technical recommendations, including cultural practices, had not yet been changed to reflect these new institutional arrangements.

It was expected that, either formally or informally, research data from the ARTs and, possibly, location-specific recommendations would reach extension. However, purchased inputs from ADMARC were still being tied to the national recommendations. Therefore, it was expected that small farmers would continue to use the generalized recommendations in the foreseeable future, even if they were less than appropriate for local conditions.

As this more decentralized decision-making process is accepted at the policy level, the new institutional arrangement will have major implications for the packaging and dissemination of extension messages. As recommendations become more location-specific, it will be increasingly difficult to collect and package technical recommendations each year in the Annual Production Guide. Instead, more and more extension messages will need to be formulated, packaged, and disseminated at the ADD level. This has direct implications for the technical competence and role of subject-matter specialists, and for increasing the communications capacity at the ADD level to insure the rapid processing and flow of location-specific research recommendations to farmers. Again, developing a flow-system analysis allows the analyst and, hence, the policymaker, to anticipate institutional problems before they become serious.

Using Flow-System Models to Simulate Alternative Arrangements

The flow-system model, as a tool of analysis, can be used equally well to simulate alternative arrangements in the process of finding workable solutions to identified problems. By explicitly outlining different alternatives that show clear linkages and institutional responsibilities, policymakers and

the key institutional actors can evaluate alternatives and make reasoned judgments about which approach appears most feasible. Furthermore, once agreement is reached and/or a decision is made, policymakers and each institutional leader will have a clear implementation plan to follow.

An example of how this technique can be used comes from a third country, where the following institutional model is currently under consideration by policymakers for possible implementation. The problem identified was the lack of well-trained staff at the provincial level to conduct on-farm trials and to provide technical and professional backstopping and training for extension personnel. In this case, an agricultural university with a relatively well-trained faculty is centrally located in the province. However, because of a historical division of labor, the university is largely a teaching institution, with the faculty conducting little research of practical relevance.

Ministry officials recognize that these human resource and linkage problems exist and that there is inadequate capacity to develop and disseminate location-specific technology. The vice-chancellor of the university would like to see his institution get more involved in practically oriented research and outreach programs, both for what they will do for farmers in the province and for their impact on classroom teaching. The flow-system model depicted in Figure 15 shows the institutional arrangements for developing a university outreach program that would be fully integrated with research and extension. The new university outreach program would carry out three functions: (1) assist with on-farm adaptive research trials, (2) help prepare extension materials and teaching aids, and (3) help conduct in-service training and technical backstopping of field extension personnel. If this arrangement were adopted, it would help carry out needed research and extension support to make location-specific technology more widely and readily available to farmers in the province.

Concluding Observations

This section contains observations on the analytical framework, the indicators and their measures, and the process of mapping the flow-system models. These are based on the overall analysis, as well as on field experiences.

The Indicators and Measures

A key element in the analytical framework is the indicator. One assumption on which the study is based is that the analytical framework adequately reflects existing agricultural technology systems. It is the indicator, acting as a tool of the framework, that measures the inputs, activities, and outputs of the existing technology system. This, in turn, permits the description and analysis of a technology system. The analytical framework itself is based on

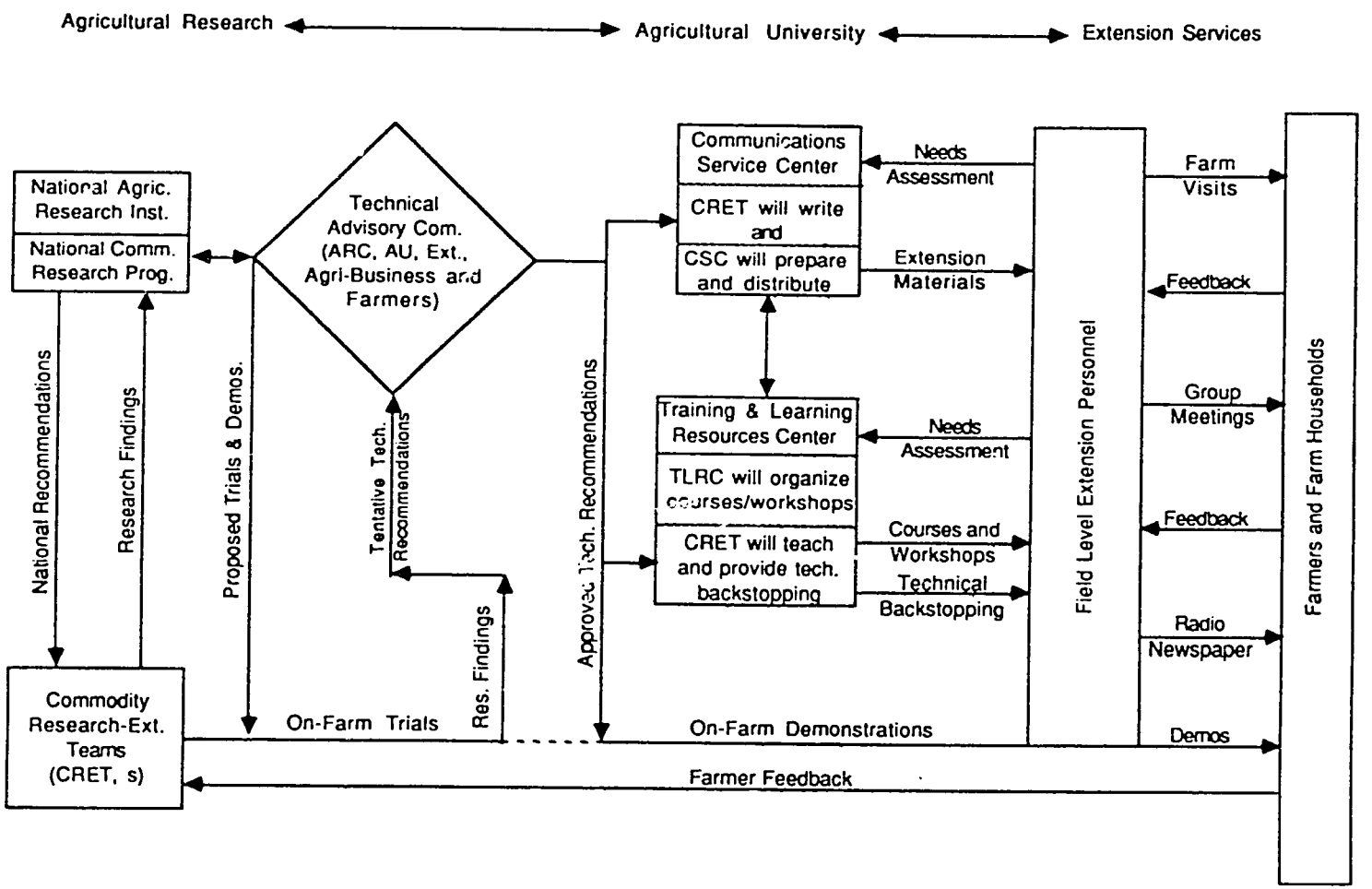

Figure 15. Functional linkages between project components and institutions

a systems approach, which provides a holistic perspective on national agricultural technology systems. This approach views a national technology system as a functioning whole composed of subsystems, along with their elements and linkages. Used as a diagnostic tool, the analytical framework identifies constraints that impede the flow of technology to the farmer.

The indicator also functions as a connecting mechanism between the analytical framework and the fit to reality that supports it. The indicators act as an interface between the framework and the empirical reality by being the focus of the analytical activity—the entre to the literature and empirical data, and thus to the testing and refinement of the diagnostic instrument.

Finally, it should be emphasized that measures associated with each indicator are as important as the indicator itself. The measures address those functions of the technology system that are reflected in the systems macromodel. A range of measures is necessary for each indicator in order to encompass the variability of data available in the real world of national technology systems.

The Flow-System Models

In reviewing the INTERPAKS experience in using the flow-system methodology, four observations appear warranted. First, the mapping exercise used in constructing the system model(s) is designed to capture the shared knowledge of all major groups in the national technology system in terms of how technology flows through the system. This is not to say that all participants will be fully knowledgeable about the entire system; in fact, few, if any, individuals will have this type of holistic view. However, through interviews and other data collection with key participants in the system, it is possible to construct a flow-system model that accurately reflects their collective viewpoint about how the national system operates.

Second, in the process of mapping the system, it is relatively easy to identify institutional or linkage constraints. Just ask the different actors in the system if technology is being received or is getting through; bottlenecks in the system will be quickly identified. However, diagnosing the actual problem(s) may take more indepth knowledge about the particular type of institution or constraint being addressed. Another difficulty in defining problems is that no group will readily take responsibility for the problem or constraint; instead, one group will blame another group and vice versa.

Once such a bottleneck or constraint has been identified, then the task of the analyst is to clearly define the problem. Here, the analytical framework provides a useful set of tools. The indicator analysis provides considerable objective data about the system in terms of the resources, activities, and

outputs of each system component; from these data, the analyst has an excellent overview from which a more indepth analysis of a particular constraint can be pursued. For example, is the problem a resource constraint, or is the output from one component (i.e., research) inappropriate for the next step in the technology system (i.e., extension)? Is it an inter- or intrainstitutional communications problem, or are the institutional policies too rigid to allow technology to systematically move through the system? Only by carefully listening to each point of view, combined with objective information from the analytical framework, can the problem be clearly understood and then communicated to others.

A third value of the flow-system model is its ability to simulate possible solutions to these institutional or linkage constraints. Since the flow analysis is particularly useful in identifying and defining these types of problems, the same modeling technique can be used to propose alternative arrangements to solving the identified problem(s). By proposing these alternative approaches in the form of a new flow-system model(s), key institutional actors and policymakers can sit down and reason through alternative arrangements to select the most workable solution to the problem. Once agreement has been reached and/or a decision made, then all of the key actors will have a clear mandate about next steps, the responsibilities of each institution and an explicit plan for implementation.

The fourth and final value of the flow-system model, in both defining problems and proposing solutions, is its usefulness in helping policymakers and system managers see the various components and linkages as essential functions of an integrated system. Again, it is the holistic view of the system provided by the flow analysis (explicitly showing the functional responsibilities of each institution and how they are supposed to link together) that recommends this approach. Rather than institutions being merely black boxes that consume resources and produce outputs, this type of analysis allows policymakers and system managers to have a comprehensive view of the system, so they can accurately evaluate constraints and thereby make constructive interventions.

Assessment of the Analytical Framework

After reviewing the literature, implementing the four case studies, and considering the findings, there appears to be substantial reason to believe that the resulting analytical framework presents a new and viable approach to addressing a major constraint to agricultural development: increasing and sustaining the flow of new agricultural technology to farmers.

First, the analytical framework is a departure from other approaches addressing agricultural technology systems. The framework is designed in a

holistic mode. Instead of emphasizing one or two components of the technology system, such as government policy on agricultural credit or agricultural research, the framework considers the entire system. As described above, it includes public policy, technology development, technology transfer, technology utilization, and the linkages that connect them as the primary components of the system.

The framework makes a logical expansion of what has been called the agricultural knowledge system. In addition to the research, dissemination, and user subsystems that make up the agricultural knowledge system, it adds the public-policy subsystem that creates the environment for the technology system and directly influences resource allocation to components, institutional arrangements, and stability. It also recognizes that linkages that connect the components are essential to a functional system. This guides the analyst or policymaker who plans to modify the system to consider a wider, more realistic range of factors that may affect the technology system. Because the framework more successfully reflects reality, it is more capable of addressing the complex situations found in national technology systems. The expectation is that data collection and assessment will be more complete and accurate when using this framework instead of other more ad hoc or narrowly focused approaches.

The analytical framework also performs well in the field, although it requires an experienced team to apply it effectively. One purpose of designing the analytical framework was to create a flexible structure capable of guiding data collection and assessing data from any technology system. The framework has this capacity in that it has successfully diagnosed four national systems that varied in degree of development and in size and geographic location of the countries. For example, in Taiwan, the framework was used to examine a highly developed technology system. It was also used in Malawi, a newly developing country, and in Mexico and Ecuador, which are newly industrialized countries.

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INSTITUTIONAL INFRASTRUCTURE AND PLANNING AND MANAGEMENT SYSTEM FOR AGRICULTURAL DEVELOPMENT: THE USE OF SYSTEMATIC CONSTRAINTS ANALYSIS IN SETTING PRIORITIES

Takaaki Izumi

Abstract

Over the past decade, the College of Tropical Agriculture and Human Resources and the state government of Hawaii have taken a pragmatic and systematic approach to the organization, planning, funding, coordination, and management of agricultural research and development in the state. The system involves a statewide agricultural coordinating body, a flexible pool of funds for project implementation, and a process of agricultural industry analysis (AIA) to set priorities. The AIA process has focused largely on commodities, but its basic concepts and procedures can also be applied other sectors and subsectors. In recent years, the systematic constraints analysis process (SCAP) has been used to design an agricultural development project in Jordan and is currently being used to plan agricultural development in the American Pacific Islands. The system, as applied to planning in Jordan and the American Pacific, is described in detail, and examples of SCAP's products are provided.

Introduction

Over the past 10 years, the College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii, and the state government of Hawaii have succeeded in taking a pragmatic and systematic approach to the organization, planning, funding, coordination, and management of agricultural research and development projects in the state. Because of its potential application to developing-country situations, Hawaii's system was

taken as a model to design the AID-sponsored Highland Agricultural Development Project (HADP) in Jordan.

Currently, the system is being used to plan the agricultural development of the American Pacific Islands, which include entities with characteristics of less-developed countries (LDCs). Initial regional analysis/action plans have been prepared for the agricultural sector, faculty/staff development, communications/data base, and crop protection through application of the systematic constraints analysis process (SCAP). SCAP is defined as *a process of planning based on systematic analysis of the constraints that are impeding the development of a sector or program / subsector, and the setting of priorities for actions necessary to overcome them in order that the sector or program / subsector may achieve its full development potential.*

Effective agricultural development requires a long-term commitment based on strong political leadership and public support; favorable policies and priorities; sustainable natural, infrastructural (both physical and institutional), human, and financial resources; an industrious and progressive agricultural sector; the ability to adapt, test, and apply appropriate and usable technologies; clear direction and effective management of programs; and viable markets for the products. These formidable challenges can be met only if effective use is made of limited resources in overcoming the constraints impeding the attainment of agricultural development objectives.

Agricultural Development Infrastructure and Management System for Less-Developed Countries

Many international agricultural development projects have experienced only limited success, especially in sub-Saharan Africa. There is a need for better project designs; stronger commitment to institutional development; improved policies and financial support; appropriate technologies for solving the problems at hand; and a sharper focus on improved management skills, delegation of authority, accountability, and administrative controls (Malone and Nawaz 1984: 21-25). A major effort in this direction is being made by the Special Program for African Agricultural Research (SPAAR), a group of donor organizations including the World Bank.

Criteria for an Organization, Planning, and Management System

SPAAR and others have perceived that the limited capacity of national agricultural research systems (NARS) is the most serious constraint on the adoption of new knowledge and technology by LDCs (SPAAR 1987). Jointly, with the SPAAR working group, the International Service for National Agricultural Research (ISNAR) authored a report entitled "Guidelines for Strengthening NARS in Sub-Saharan Africa" (ISNAR/SPAAR 1987), which

provides an analysis of the organizational, planning, management, and resource needs of African NARS. Basically, these include the following:

1. A national agricultural research and development infrastructure that facilitates (a) dialogue and decision making by policymakers and decision makers, research and extension managers, and the clients of agricultural development programs; (b) acquisition and disbursement of funds for implementing actions; (c) competitive salaries and flexible personnel policies to recruit and retain competent staff; (d) coordination of programs within and between the public and private sectors; and (e) effective management of agricultural development of personnel.

2. A planning and management system that would (a) actively involve and facilitate communication and collaboration among policymakers, administrators, researchers, extensionists, clientele groups, and other interested individuals; (b) address relevant policy issues such as development objectives and priorities, land ownership and tenure, farmer incentives and disincentives, and pricing and marketing; (c) give attention to environmental resources and their sustainability; (d) analyze and set macro- and micropriorities for constraints impeding agricultural development and delineate the actions needed, including technology adaptation and transfer; (e) be applicable to commodities, resources, educational and technical programs, and farming systems in recognition of their interrelationships; (f) provide for effective implementation, monitoring, and evaluation of programs and projects; and (g) facilitate networking and collaboration with national, regional, and international agricultural research institutions.

These criteria exemplify and are reflective generally of the conditions and needs found in many LDCs, not only those in sub-Saharan Africa.

Need for a Flexible and Pragmatic System

Another report (Walton 1984: 35-36) describes the stages through which agricultural development projects have evolved: (1) single-crop projects that have the advantage of simplicity and have been comparatively successful; (2) area-based agricultural and rural-development projects that are much more complicated, frequently have special project management units, and seem to get bogged down in complexity; (3) national programs that attempt to simplify project design, work through existing institutions, deal with policy issues and usable technologies, and have achieved some successes; and (4) projects that attempt to create favorable policy and institutional environments and seem to offer prospects for success if a balance can be maintained between the national macroeconomic concerns of policymakers and the micro-operational needs of farmers.

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It can be concluded that there is a need for a system that provides for setting priorities from both the national point of view and that of farmers, and that can flexibly approach the development and implementation of technology from the standpoint of a commodity, an educational or technical program, or a farming system, as appropriate. *However, these studies stop short of recommending a specific structure or system.*

The Hawaiian System

Like other American land-grant institutions, the basic mission of the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii is to carry out instructional, research, and extension programs that meet the needs of agricultural industries and business in the state. However, the manner in which the college has organized itself (and plans and manages its research and development programs in collaboration with the state) is somewhat unique.

Organization and Management System

As reported earlier (Izumi 1986), the CTAHR undertook a major reorganization about 10 years ago to improve the coordination of research and extension so that the latter functioned as a continuum or source of feedback of the former, and priorities concentrated on the needs of the state's agricultural sector and consumers as well as of the academic disciplines. The Hawaii Institute of Tropical Agriculture and Human Resources (HITAHR), which amalgamated the traditionally separate Hawaii Agricultural Experiment Station and the Cooperative Extension Service, was established.

HITAHR has implemented an agricultural industry (commodity/resource subsector) analysis (AIA) process which it carries out on behalf of the Governor's Agricultural Coordinating Committee (GACC). This process draws upon representatives from the subsector (farmers, cooperatives, grower organizations, agribusinesses), pertinent country, state and federal agencies, and a multidisciplinary team of research and extension faculty to conduct a systematic analysis of that subsector. The analysis determines the bottlenecks preventing the subsector from achieving its full potential and sets priorities for actions to be taken by applicable agencies and by farmers themselves to overcome the constraints, including the estimated cost, time required, and probability of success of the actions. When accepted by the subsector representatives, the resulting analysis/action plan is presented to the GACC. If approved by the GACC, it officially becomes the state's action plan for that commodity. The GACC has a flexible pool of funds that it uses to contract with the university for research and extension projects determined by the AIA process to be of high priority.

Since the AIA process was initiated, more than 60 analyses involving nearly 30 major commodities have been completed, most of them for two or more times. These commodities represent about 95 percent of the total farm-gate value of all commercial commodities produced in the state. Approximately 60 percent of the agricultural research projects in the CTAHR directly address constraints identified through the AIA process.

Although the process has had a significant impact on agricultural development in the state, it has been relatively unpublicized.

Adaption of Hawaii's System to Jordan

As defined in the project paper (USAID 1985), the primary purpose of the Highland Agricultural Development Project (HADP) is to strengthen and institutionalize Jordanian agricultural research and extension capabilities in support of highland and national agricultural development.

Organizational Principles

The following principles guided the design of the project: The HADP will provide for institutionalization of research and extension capability through a National Center for Agricultural Development and Technology Transfer (NCARTT) and a high-level agricultural-development council (ADC), The ADC and NCARTT should have the mechanism and flexibility to address changing needs through continuous analyses of national agricultural development requirements. Regional agricultural service centers (RASCs) will conduct field experiments, on-farm demonstrations, and workshops and disseminate information. The NCARTT should take advantage of available research capabilities and technology and will collaborate with in-country, other national, regional, and international organizations, as well as participating in regional and global agricultural information networks.

These principles will be realized through buildings, facilities, equipment, technical assistance, training, and a development fund provided to the NCARTT and ADC through the HADP.

Planning and Management System

The HADP design called for a planning and management system based on Hawaii's AIA process. Because the term "agricultural industry" was not in common usage in Jordan, the process was redesignated as the systematic commodity/resource analysis and development (SCRAD) process.

The concepts and procedures of the process are not difficult to learn; actions and priorities can be decided by consensus, even with limited data (as is

often the case in LDCs), and the system is relatively easy to get started. The Jordanian director of NCARTT and a researcher received three weeks of SCRAD training in Hawaii. They were able to produce a draft analysis/action plan for Jordan's wheat subsector, which was the first known application of the process to an LDC situation. Upon their return to Jordan, they wrote and presented a paper titled *Systematic Commodity Resource Analysis and Development Process and Its Implementation for Jordan Agriculture* (Abu Salah and Ghosheh 1987) to an NCARTT in-house workshop.

Despite SCRAD's favorable reception and demonstrated efficacy, the technical assistance team and AID mission decided to concentrate first on developing farming-systems research. This departure from the original project design has delayed the implementation both of the SCRAD process and of priority action plans utilizing the ADF.

The Agricultural Development Fund (ADF)

The ADF ($10,250,000 over the seven-year life of the project) is an extremely important device that drives agricultural development. It does this by providing supplemental funds for allocation by the ADC to address major constraints, implement SCRAD action plans, underwrite land aggregation and crop demonstration projects, and contract for research, farm machinery, and other input services.

Other Project Activities

Agricultural credit agencies and agribusinesses will be provided technical assistance. A demonstration of range rehabilitation will be conducted in cooperation with livestock cooperatives. Attention will also be given to the socioeconomic needs and constraints of farm families and women in order to improve the quality of rural life.

The Systematic Constraints Analysis Process

Because the application of the process has evolved beyond commodities/resources to comprehensive agricultural sector and program/subsector planning, a broader term, systematic constraints analysis process (SCAP), has been adopted.

SCAP Procedural Steps

The procedural steps for applying SCAP to the development of the agricultural sector and programs/subsectors (commodity, natural or human resource, technical, or farming-system programs) are as follows:

1. The program leader convenes a multidisciplinary sector or program/subsector task force of researchers, extensionists, and other knowledgeable persons to conduct and prepare the analysis in accordance with the worksheet format (see Figure 1).

   a. The program elements or components that determine the sector's or program/subsector's development are defined. A flowchart depicting the sequence and process of interactions leading to program objectives/development is prepared.

   b. The current status, objectives, underlying assumptions and potential of the sector or program/subsector are described.

   c. For each program element/component, the constraints impeding progress and attainment of the sector's or program/subsector's potential are identified.

   d. The actions required to overcome the constraints, including adaptation of technology, are determined.

   e. The agencies or organizations responsible for taking action (i.e., those most qualified to do so) are designated.

   f. The probability of the action's success is predicted.

   g. The time required to achieve results is estimated.

   h. The amounts and sources of current and additional resources required to carry out the action are projected.

   i. The impacts if the constraint is not overcome and/or the benefits if the constraint is eliminated are described.

   j. Tentative priorities among proposed actions are set.

2. The draft worksheet is prepared by the program leader and circulated among the task force members for additions, corrections and revisions.

3. A revised worksheet is given full distribution and a meeting is called to obtain inputs from a wider audience of pertinent officials, clientele, and agribusiness representatives. Full consensus is reached on the needed actions and on the priorities.

4. The worksheet is then separated into a narrative analysis and the prioritized action plan.

Priority	Bottleneck	Action Required	Agency Responsible	Possibility of Success	Duration	Resources			Impact if bottleneck not eliminated
						Required	Allocated	Source	

Figure 1. SACP worksheet

5. The analysis/action plan is presented by the program leader to the ADC for approval. The ADC may alter the priorities if there is strong justification for doing so.

6. Designated action agencies, including instructors, researchers, and extensionists, submit project proposals to address the constraints identified in the SCAP action plan.

7. If appropriate, supplemental funds from the ADF are allotted by the ADC for project implementation.

8. Each SCAP analysis/action plan is revised periodically (usually every two or three years), based on a progress report which is prepared through the same task force process. The report indicates the constraints that have been resolved, the status of each remaining constraint, and new problems or needs that have emerged. Priorities are also updated.

The above procedures would be subject to modification as necessary to fit the situation prevailing for each analysis.

Pragmatic Approach to Setting Priorities

Priorities among necessary actions are decided through a consensus of the task force members based on their knowledge, experience, and "expert" judgment. The kinds of factors taken into consideration in reaching priority decisions are as follows (not necessarily in order of their importance):

1. the importance or economic potential of the program/subsector to agricultural development and/or as a food or source of nutrition if it is a commodity;

2. the number of times a problem (such as lack of trained staff, land, or capital) appears as a constraint for more than one program/subsector;

3. the severity of damage or loss if the problem (such as disease or contamination) is not immediately addressed;

4. the present and potential need or market demand for the product (including university graduates);

5. the importance of the constraint to the program/subsector's objectives and/or potential;

6. the time and cost involved in overcoming the constraint as weighed against the benefits;

7. the availability of existing and/or additional resources (staff, labor, facilities, equipment, and operations);

8. the intensity, scope, and sources of support (scientific, political, client, and public) for taking action;

9. the total impact of overcoming a constraint (such as a road to carry produce to the market) on other agricultural programs/subsectors or even nonagricultural sectors;

10. the availability/transferability of technology to overcome the constraint;

11. whether the proposed action would duplicate work done previously, either locally or elsewhere;

12. the potential for achieving success.

The pragmatic approach to priority setting taken by SCAP would greatly facilitate the implementation of agricultural development projects.

Advantages of SCAP

SCAP has proven to have the following advantages: (1) it is very pragmatic in approach, which allows analysis to proceed and priorities to be reached by consensus, based on the planning task force's knowledge, experience, and "expert" judgment; (2) its concepts and procedures are not difficult to understand — it is relatively easy to get started and decisions and actions can be taken, based on carefully defined assumptions, without a full array of data (the lack of data may itself be identified as a constraint requiring action); (3) in addition to on-farm constraints, it systematically addresses relevant off-farm factors that affect agricultural production and development; (4) it actively involves the relevant actors and action agencies, from the policymaker to the farmer, to obtain essential inputs and gain their acceptance, commitment, and collaborative action; (5) its concepts and process can be adapted to fit the unit of planning (regional, national, district), the program or problem area to be analyzed (commodity, technical program, farming system), and the level of decision making from policy (macro) down to operational (micro); and (6) it results in action plans that are funded, carried out, and updated on an on-going basis.

The Project-Implementation, Monitoring, and Evaluation (PIME) System

After approval of the action plan, the organization(s) and individual(s) designated by the analysis as most qualified implement the prioritized action(s) as project(s) in order to overcome identified constraint(s).

PIME should be based on the USDA's Current Research Information System (CRIS), Extension Information System (EIS), or comparable systems. It involves the following procedures:

1. A researcher or specialist prepares a project proposal that includes (a) a description of the project objectives; (b) the educational (including training), research, or extension activities to be carried out; (c) principal investigator and co-investigator(s); (d) estimated duration of the project and budget; and (e) the method to be used to evaluate project results.

2. Upon approval of the project proposal by the ADC, an agreement is signed with the implementing organization and funds from the ADF are allocated for project implementation.

3. A project account is established. Expenditures are made in accordance with established fiscal and personnel procedures. The principal investigator and supervisor receive monthly ledgers showing the project's allotment, expenditures/encumbrances, and balance.

4. A CRIS "Research Work Unit/Project Description/Research Resume" or a comparable form, is filled out and entered into the management data base. Inputs for similar EIS reports should be made.

5. Once a year, CRIS and EIS progress reports are prepared for each project and also entered into the computer.

6. Immediately following the updating of the research and extension management data base, a series of reports are generated and distributed to appropriate administrators.

7. Summary project ledgers for the current fiscal year and requested budgets for the coming fiscal year are also prepared and, together with the above set of project reports, form the basis for the annual program budget review. The progress and status of each project are evaluated and a decision reached on whether to terminate it or to continue at a level of funding that is either reduced, the same, or increased.

8. Independent financial audits should be conducted.

Amalgamating SCAP Procedures and Format with Practical Aspects of Farming-Systems Research

Because SCAP (or the AIA/SCRAD process) in the past has focused on one commodity at a time, the question of its compatibility with farming-systems research (FSR) (which is multicrop in approach and thought by many to be more suited to LDC conditions) must be faced.

Experience with Farming Systems Research

Although FSR has been widely tried in many LDCs, there is no agreement over its definition, appropriate role, or efficacy. The World Bank commissioned a review of FSR, which drew some interesting conclusions: (1) FSR in practice has been more academically oriented; (2) on-farm research with a farming-systems perspective (OFR/FSP) is more pragmatic in changing farmers' circumstances, whereas other approaches often attempt to change the socioeconomic circumstances to fit the technology; (4) the role of extensionists will change since OFR/FSP brings researchers into direct contact with farmers; and (5) other approaches will still be needed because FSR is unlikely to produce the bold initiatives needed for agricultural development in some areas (Simmonds 1985).

Interdependence among Commodity, Disciplinary, and Farming-Systems Research

Other advocates of OFR/FSP (Collinson 1984; Zandstra 1987) and ISNAR have recognized the interdependence between FSR and commodity and disciplinary research, and the necessity for compatibility between farmers' and national priorities. This interrelationship has been succinctly stated by Collinson (1984):

> FSR's role in technology generation is complementary to that of traditional technical research appropriately identifying which components, in what combination, offer major development opportunities for local farming systems at any particular time. It also [provides] feedback to the relevant commodity and disciplinary specialists [on] those unresolved technical problems which are most important for local farmer development. This feedback allows inclusion of farmers' needs as a criterion in ranking research priorities.

Although FSR identifies the need for and instigates efforts at technology development, its main role has been to apply available technology to improve

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farming systems. Technology is still generated primarily from commodity and disciplinary research, which are themselves usually complementary.

ISNAR made this point:

> Farming systems research (FSR) is widely regarded as an appropriate approach for defining farmers' constraints and thus for setting research priorities. However, in taking up FSR, national research leaders and donors must address the important question of balance between FSR and commodity research and their interdependence. Many FSR projects across Africa have been over-funded relative to commodity research programs (ISNAR/SPAAR 1987: 18).

More attention should be given to commodity-based systems. Hawaii is probably one of the few places in which such a system has been methodically, widely, and successfully applied over a sustained period of time.

Compatibility of SCAP and OFR/FSP

SCAP and OFR/FSP are compatible, and their best features could be combined to form a system that can better fulfill the planning and management requirements of agricultural development in the LDCs. Amalgamation of the two processes would take place as follows:

1. All SCAP task force members will be trained in basic FSR concepts and take an OFR/FSP approach whenever appropriate.

2. FSR specialists will provide inputs into the SCAP process to ensure that OFR/FSP needs will be taken into account when setting priorities and that feedback is provided.

3. As SCAP analyses (which will have farming-system inputs) are completed, an analysis/action plan for the predominant farming system can be composited from the analyses of the commodities that comprise that farming system. Or an independent analysis can be conducted using the SCAP process and analytical format.

   The transition from commodities to farming systems is illustrated in Figure 2. It should be kept in mind that the illustration does not depict the total picture. Cutting across commodities/resources and providing inputs into the system at each stage are disciplinary/technical programs such as soil-water management, crop protection, biotechnology, engineering/mechanization, processing, nutrition, and marketing. Such disciplinary/technical inputs would be needed regardless of whether a commodity, technical program, or farming system is being analyzed.

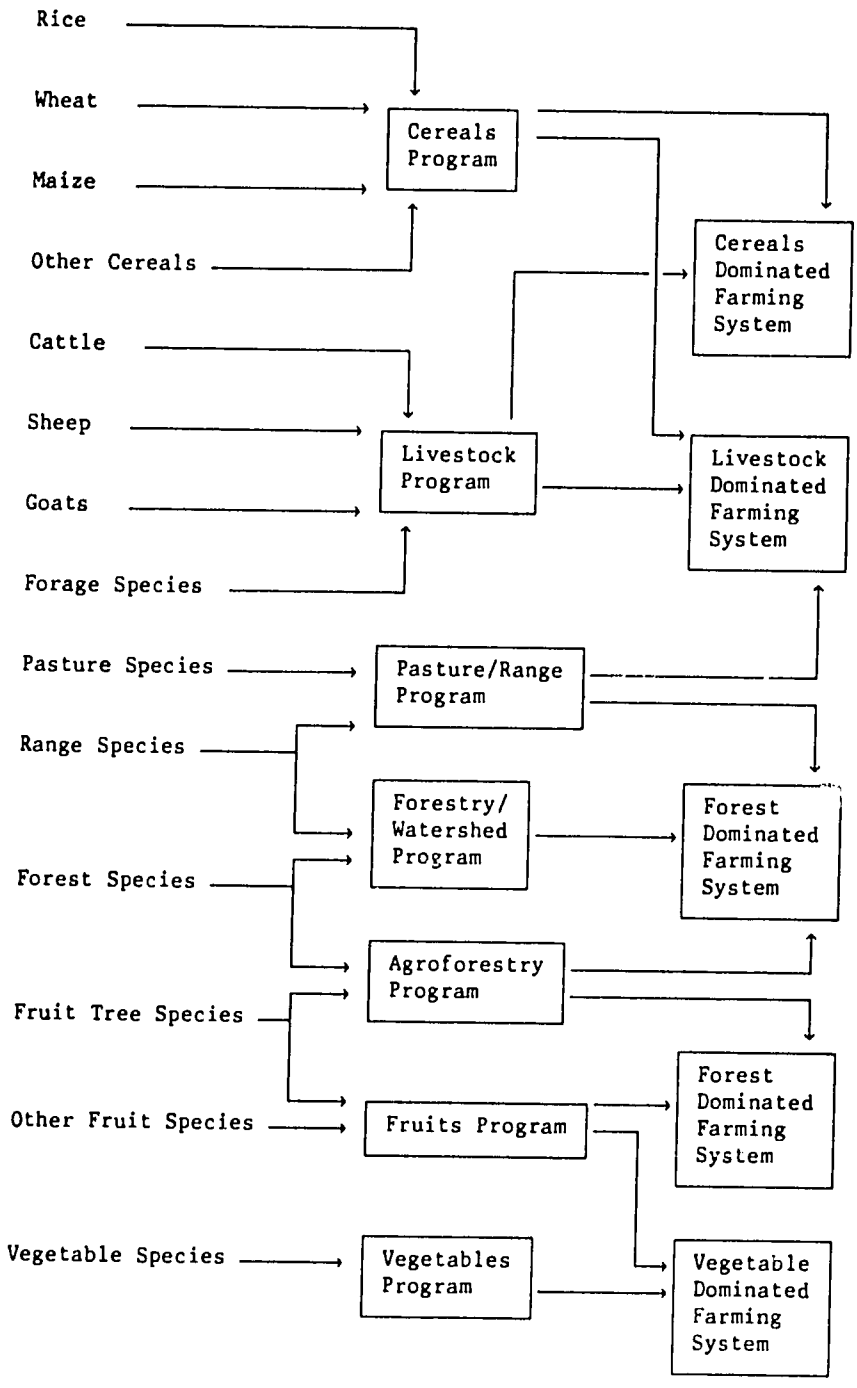

Figure 2. Transition from commodities to farming systems

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4. Projects undertaken pursuant to SCAP action plans will be implemented using OFR/FSP techniques and procedures.

5. The improvements expected to be realized are as follows: (a) the constraints faced by both the small multicrop farmer as well as the larger monocrop producer, and their requirements, will be addressed; (b) off-farm factors that are essential to increased production and agricultural development as well as on-farm needs will be addressed; and (c) using the SCAP format and process for farming systems will focus on decisions at each stage and produce an action plan for funding and implementation instead of a report that only may end up on someone's shelf.

If properly structured and administered, the amalgamation of SCAP with OFR/FSP would provide a flexible system that can fulfill the planning and management requirements for agricultural development of LDCs.

Application of SCAP to Agricultural Sector and Program/Subsector Planning

Many countries have a section on agriculture in their national development plans. However, very few have systematically addressed agricultural development in a comprehensive manner, in part because a practical and broadly applicable planning methodology has not been available. SCAP would provide such a system.

Levels and Scope of Planning

An overview of the levels of planning and program elements for applying SCAP to agricultural sector and crop and livestock subsectors is shown in Table 1.

Agricultural development takes place within total societal development which is categorized into the following sectors:

- Infrastructural sectors: water/wastewater, transportation, energy, communications, government/legal, and financial.

- Social sectors: housing, health, education, social services, and arts and culture.

- Production/service sectors, agriculture/agroforestry/forestry, fisheries/mariculture/aquaculture, tourism, industry/manufacturing/ processing, and business/service/commerce/trade.

Table 1. Planning Overview and Program Elements

National Development		Agricultural Sector Development	Subsector Development	
			Crop Subsector	Livestock Subsector
Infrastructure	Water/wastewater Land use Transportation Energy Communications Government/judicial Financial	Long-term commitment Sustainable natural resources (land, soil, water, forest, range) Infrastructural requirements (water, transportation, energy, communications) Human resources (training, staffing, personnel policies) Inputs and services (cooperatives, credit, machinery, supplies) Technology development and transfer Improved and alternative/new technologies Crop protection Farming systems Processing Marketing Nutrition and dietary improvement Socioeconomic considerations and programs Private-sector development	Water resources Land/soil Capital/credit Labor Improved cultivars Insect control Disease control Weed control Control of other pests Culture and management Harvesting Postharvest handling Processing Transportation to market Marketing Production economics Farm management Government policies, laws, and regulations	Water resources Land Capital/credit Labor Improved breeds Control of insects and external parasites Control of diseases and internal parasites Protection against toxic chemicals, poisonous plants, other hazards Reproductive performance Nutrition Environmental stress Production systems Waste management Slaughter Processing Transportation to market Marketing Production economics Pasture/range management Government policies, laws, and regulations
Social	Housing Health Education Social Services Arts and Culture			
Production/ service	Agriculture/agro-forestry/forestry Fisheries/mariculture/ aquaculture Tourism Industry/manufacturing/processing Business/commerce/trade			

The infrastructural sectors must achieve a critical minimum of development before the social and production/service sectors can begin to expand. Planning must address the constraints in the infrastructural and social sectors that impinge upon agricultural development.

Several different levels and types of plans are needed. The first is a national development plan in which there is a section outlining the major policies, goals, and actions for the agricultural sector. Next is the level at which SCAP is used to produce an agricultural-sector analysis/action plan. The third is the program/subsector level in which numerous analysis/action plans are prepared. Plans at this level can be categorized into commodities (crops and livestock), resources (human and natural), technical programs (biotechnology, crop protection, etc.), and farming systems.

Defining Program Elements

The first and most important step in SCAP is the identification of program elements (also referred to as components, factors, variables, and determinants) that determine the sector's or program/subsector's development. Program elements differ according to the level of planning and nature of the program being planned. A set of uniformly applicable program elements has each been defined for crops, livestock, and the agricultural sector as a whole and can probably be developed for farming systems. However, a set of unique program elements will have to be defined for each resource-management (soil, water, forestry, education, and training, etc.) and technical program.

Program Elements for the Agricultural Sector

The program elements for the agricultural sector must be comprised of the determinants of agricultural development, must be reflective of objectives, and must provide a framework for addressing the proper constraints. The program elements which have been defined are

1. long-term commitment (government and business leadership, clientele/community/public support, favorable policies, development funding and accountability);

2. sustainable natural resources (land, soil-water, forest-watershed, range/pastures);

3. infrastructural requirements (water/irrigation, transportation/storage, energy, communications/data systems);

4. inputs and services (cooperatives, credit, and agricultural chemicals, machinery/maintenance, supplies);

5. technology development and transfer (research and extension capability, appropriate technology);

6. improved and alternative/new commodities (consumer/biotechnology/bioprocessing revolution, agroforestry, crops, livestock/forage/feed, fisheries/mariculture/aquaculture);

7. crop protection (biological control/integrated pest management, registration and safe use of pesticides);

8. farming systems;

9. processing (intermediate/value-added processing);

10. marketing (import substitution, quality standards, product recognition, and safe use of pesticides);

11. nutrition and consumer trends (dietary improvement, consumer education, diversification of diet);

12. other socioeconomic considerations and programs (socioeconomic constraints, women in agricultural activities, welfare of children, family resource management, community leadership, dealing with rapid societal change, etc.);

13. private-sector development (bureaucratic constraints, privatization, private-sector initiatives).

Program Elements for Commodities

The program elements for crops are water resources; land/soil; capital/credit; labor; improved cultivars; insect, disease, weed, and other pest controls; culture and management (fertilization, irrigation, sowing, spacing, cultivating, pruning, etc.); harvesting; postharvest handling, processing, transportation to markets, marketing (market development, promotion, supply, demand, price analysis); production economics; farm management; and government policies, laws, and regulations. Similar program elements with appropriate modifications have been defined for livestock subsectors.

Initial analysis/action plans on regional agricultural-sector development, faculty and staff development, crop protection, and communications/data systems for the American Pacific islands have been prepared. Program elements and analysis/action plans for other program subsectors will be developed utilizing SCAP.

SCAP is a pragmatic planning methodology that can be broadly applied. Its proven concepts, procedures, and versatility come as close as possible, without a prolonged and expensive effort at system development, to meeting the criteria for a workable planning and management system for agricultural development in LDCs.

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Special Cases

METHODS FOR DIAGNOSING AGRICULTURAL RESEARCH CONSTRAINTS IN SUB-SAHARAN AFRICA

Arthur J. Dommen

Abstract

Agricultural research has had limited impact in sub-Saharan Africa. Attempts to transfer modern biological and mechanical technologies have been unsuccessful. This paper argues that scientists' failure to conceptualize the mixed cropping systems of low-resource African agriculture in a manner that treats conservation of resources as an output similar to annual crop output has impeded research progress. Insights permitting such a reformulation of the classical production function have been recorded over the years by many perceptive field observers, but these have not been systematized so as to inform the research effort on the physical science side. This paper contributes some methodological proposals.

Introduction

Rather than setting forth here a rigorous theory of low-resource agriculture (LRA)[1] in sub-Saharan Africa (which I have done elsewhere), I would like to share with you today some of the insights that in part formed my view of the efficiency of LRA and its scope for further improvement through research. I think this is the best way to start. Then, continuing for the moment in a diagnostic vein, I will attempt to suggest how these insights lead an economist to approach the problem of change in LRA differently from the physical scientist. Finally, I will propose some methodology in this general area of diagnosing the agricultural research constraints we face.

[1] I have defined *LRA* as agriculture that relies primarily on internal inputs (farm-produced seed, family labor, simple hand tools, manure and organic wastes, minerals from ash) rather than on external inputs (commercially produced seed, hired labor, power tools, chemical fertilizer).

De Wilde (1967), in his classic study published more than 20 years ago, recognized the divergence of approaches to the problem. As he wrote then, and as is true today, "It is above all necessary that the work on the sociological, economic and more purely technical aspects of agricultural development be closely integrated" (De Wilde 1967: 47). It is significant in this regard that De Wilde's team was an interdisciplinary one, comprising a tropical agronomist, an anthropologist, and two economists. The constraints to research on agriculture in Africa have not changed much in the interim.

I will advance the hypothesis that the failure to achieve breakthroughs in the development of LRA in Africa is due to the failure of our attempt at a successful synthesis between the economic and the "more purely technical aspects." This failure is primarily a problem of mental attitudes in how to approach research on LRA. I include on the economic side the analysis of factor productivities, which is vital to the success of any research effort and justly deserves to be part of the synthesis. Such analysis is part of the economist's tool kit, having to do with the way the producer decides to use resources in production. I will also have some things to say about the physical scientist's tool kit and how it is used.

Insights

The idea that change in LRA itself occurs gradually rather than dramatically was certainly an important early insight, and one that was available to those on the lookout for insights, whether they were physical or social scientists. Yet it is often completely overlooked. I was happy to find recently while thumbing through my notes from a research seminar we held in ERS in June 1982 the following hypothesis about change:

- Technological progress in Africa is likely to take the form of incremental change, marked by use of critical inputs in greater quantities, rather than by dramatic quantum jumps. This means [that] a 0-1 measurement criterion is invalid.

This hypothesis of mine deserves two observations with the benefit of hindsight. First, it was heresy in the true sense of the word, for the believers in quantum jumps in food production in sub-Saharan Africa resulting from technological change (at least at that time) represented the mainstream of development thinking. My own choice of words shows what a firm hold technology had on us all, and what an obstacle to understanding it was: the kind of incremental change I had in mind was not technological change at all.

Second, the 0-1 measurement criterion (adopters versus nonadopters) was very much a standard data-collection requirement in the evaluation of development projects based on high-yielding varieties like the World Bank-funded regional projects in Nigeria (IAR). Analysts concentrated on finding out how the new technology impacted on farmers, not in finding out how farmers affected technology or its development. Use of the 0-1 criterion raised a host of equity issues, since it was found that adopters were often larger, or what were called "progressive" farmers. The criterion served in analyzing the "after-the-adoption" situation but told little about the "before-the-adoption" situation, and as such, it was invalid for research into the question of technological progress.

Later on, I found the above hypothesis expressed much more elegantly by others. Paul Richards (1985), notably, went a step further and linked the idea of ecological soundness to the gradual change that was taking place, so gradual, in fact, as to be mistaken for stagnation. Richards claims that he received the initial stimulus to formalizing what he has happily called indigenous agricultural revolution from his seven years of teaching agricultural geography at the University of Ibadan (Richards 1985: 6). Anyway, the generalization of his own and his students' observations in Sierra Leone and Nigeria marked a very big step forward for those interested in African agricultural research. Dupriez (1982), drawing on the extensive literature in French, enunciated the principle of conservation of biomass equilibrium in African agriculture, but his attempt to translate this principle into a production function was flawed by the fact that his outputs were additive and therefore independent of one another.

The task of analyzing change in LRA that is not dependent on technological change, as the economist understands the term, was greatly facilitated by the presence in our tool kit of the theory of organizational innovation first enunciated by Schumpeter (1939) in the 1930s. A change in the way resources are organized for production was sufficient to shift the production function, Schumpeter posited. The view that organizational innovation is a common aspect of LRA is confirmed in the observations of economists who have studied the agricultural production systems in the semiarid tropics of West Africa.[2] There, the concentric ring pattern of fields strikes even the casual visitor and has been described by Pélissier (1983) and other geographers. But the key insight, again, has been to systematize random observations into the logic of economic theory. (In much the same way, Von Thuenen systematized the spatial organization of the countryside of 19th-century Europe.)

[2] Further reading served to confirm that organizational innovation is a feature of the African tropical rain forest zone as well as of the semiarid tropics.

Prudencio (1966), studying input-output relations in a village in Burkina Faso for his dissertation research, saw the concentric ring layout of fields around the household compound as a representation of different levels of management — so much so that he used the term "management rings" in tabulating his data on inputs and outputs by field location. In other words, organizational innovation in LRA, seen in cross-section in a single village at one point in time, was something deliberate, something under the control of farmers — in other words, something wished. Extended logically from the spatial to the time dimension, this implied of course that farmers could and would intensify their production on the same field over time under appropriate conditions, such as increasing population pressure.

Farmers have acquired a good feel for what crops to plant on what sorts of soils. By planting crop mixtures, they are able to take advantage of synergistic relationships between the foliage and root systems of different crops planted side by side. They also know that to prevent erosion they should keep a crop cover on the soil to the greatest extent possible. So they carefully adjust their crop mixtures to suit their soils, both under the short-growing-season conditions of the semiarid tropics and under the long-growing-season conditions of the tropical rain forest.

There are a number of other advantages to mixed cropping besides maximizing total output. Minimizing the risk of crop failure, using resources like labor to best advantage, and providing flexibility within the growing season are some of them.[3] It is small wonder that Richards (1983: 27) has described mixed cropping as "one of the great glories of African science."

Granted the rationality of mixed cropping, the actual selection of crop mixtures has to do with differences in soil fertility on the same farm, which impose different opportunity costs on the other inputs the farmer uses. As is well known, crops have rather specific requirements for soil nutrients and soil moisture. But soil fertility, while fixed in the short run, becomes variable in the long run, being a function of the crop sequence and cultivating practices a farmer uses, as Prudencio (1966) notes.[4] Crops and cultivating

[3] Those who wish to remind themselves of the extraordinary flexibility of LRA may read Pelissier's (1983) description of how the cereals sorghum and millet are complementary in numerous ways (e.g., resource use, risk minimization, nutrition) for the farmers in the peanut basin of Senegal (Pelissier 1983: 423, footnote 1). Pelissier's monograph is a model for this sort of research.

[4] Prudencio (1966) states the following: "Crop sequences from the point of view of farmers in the region are a major means of maintaining soil fertility" (1966: 63). "In this study, the specific nature of the crop sequence has been selected as the categorical variable because crop sequences, especially those that involve fallow and legumes, are more widely used to regenerate soil fertility than fertilizer sequences" (1966: 73). "Each management ring contains a small number of simple and homogeneous management practices, which are defined in terms of the specific nature of the crop sequence and in terms of the exact combination of other soil fertility regeneration techniques (fertilizers, fallow) as explained earlier in this chapter" (1966: 87).

practices differ greatly among Prudencio's management rings: close to the compound, fields of maize and red sorghum benefit from household wastes in addition to manure, and labor input goes into building small dikes or tied ridges, while in the outfields, crops like millet and white sorghum are sown with hardly any soil preparation at all. Prudencio's key insight was that the movement from a less intensive management ring to a more intensive management ring represented an upward shift of the production function. Here was gradual change explained in an economic framework we could readily put to good advantage to extend our knowledge beyond the rather limited horizon of scattered insights.

The tendency to see crops in isolation from each other, instead of as part of a mixture associated with a particular intensity of farm management, has been a serious obstacle to scientific wisdom about LRA in Africa. The following statement about new crop technologies reflects the prevailing view:

> While these technologies all represent sole crop production, their simplistic nature would suggest that incorporating them into existing farming systems would not pose too serious a problem (Abalu and D'Silva 1979: 7, footnote 1).

The readiness of agricultural economists to accept the assumption that mixed cropping systems behave the same way monocropping systems behave is genuinely alarming.[5] This stems from our tendency, especially after the Green Revolution, to see technology as embedded in particular crops. It is not the nature of new technologies, simplistic or otherwise, that poses the problem, of course; it is the complex and highly integrated nature of mixed cropping systems into which scientists (or, more properly perhaps, the managers of development projects) persist in trying to insert these new technologies. To the present day, most treatments of African agriculture fail to point out that mixed cropping is the rule, and this poses special problems for research and project design.

The rather muddle-headed thinking that economists have on occasion demonstrated about LRA arises from a narrow focus on technology that hinders an appreciation of how resources are being used more efficiently, broadly speaking, in production. Binswanger (1985: 16), realizing this, protested against "the obsession with yield which most agricultural specialists from

[5] It was only when I read Steiner (1984) that the implications of mixed cropping for even relatively simple research problems like recommending optimal fertilizer doses really dawned on me.

the developed world or from Asia bring to Africa" as counterproductive to research.[6]

Intensification of production means the transition to the use of greater quantities of variable factors per unit of the fixed factor. For economists using the Asian model of development, land is the fixed factor of production. But in LRA in Africa, farmers use land through time, as it were. In fallowing systems, land is not cropped continuously year after year but is allowed to restore its nutrient stock through reversion to bush or forest. Land is thus taken out of production for several years at a time. Normalizing on yields per hectare in abstraction from the time dimension has little economic meaning. We see here how such abstraction results in a completely falsified analysis of factor productivities.

Abundant empirical evidence pointed up the problems with this narrow focus. Yudelman (De Wilde 1967: 58) noted as early as 1964 that labor use per hectare did not go up in many cases in East Africa, even . here export crops are grown.[7] The obstinateness of African farmers in using animal-drawn implements to expand their area of cropping instead of to farm the same area more intensively constituted a puzzle to many observers blinkered by this narrow focus.

In circumstances where the wrong denominator was being used in measurement, the general idea was propagated that both land and labor productivities in African LRA were low and could not easily be raised to higher levels through introduction of land- and labor-saving technologies in the classical fashion.

Insights regarding the gradual nature of change, the critical role played by organizational innovation, the link between crop sequences and soil fertility, and the facilitating role of mixed cropping (not, let me emphasize, to the introduction of new technologies from outside, but to the evolution of cultivating practices from within) permitted the construction of a coherent theoretical framework in terms of a production function of LRA. Annual crop production and conservation of equilibrium biomass are joint products, not additive in function. Normalizing on the fertility aspect of land, which is the

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[6] More recently, Binswanger and Pingali (1988) have touched on the demoralizing effect on research of making high yields the focus of research efforts: "No matter how good research and extension is in such places [where land is still abundant and market access is poor], farmers will not be interested in fertilizers, irrigation, fertilizer-responsive seeds, elaborate crop husbanding, or land improvement and conservation. In such conditions, asking research and extension workers to propagate high yields is a recipe for demoralizing them" (1988: 93).

[7] De Wilde (1967) was led to conclude that what Yudelman had described was a case of the target income hypothesis.

really fixed factor in the short term, produces meaningful analytical results. Then the empirical observations of many field-workers make more sense.

Some of these field workers, like the anthropologist Guyer (1984), were investigating matters affecting agricultural production even if not agricultural production per se. Others were managing development projects and happened to have more than the usual quotient of inquisitiveness, like Becker (1974) and Fresco (1986). Even those describing integral components of the agricultural system may have had other mental models in mind, like Diehl and Winch (1979) in relating the length of cropping-fallow cycles in central Nigeria to soil fertility. More often than not, such observations were "buried in a mass of information whose relevance, if any, is not readily apparent to the practical agriculturist," as De Wilde observes (1967: 47).

These extremely valuable observations reassured me that African farmers behave rationally and that their behavior is susceptible to analysis using the economist's tool kit. They also persuaded me that my conceptual framework, which separates out the fertility-related attributes of land from its purely areal aspect and normalizes on that variable (fixed in the short run, susceptible to change in the long run) was sufficiently robust to accommodate empirical verification (besides providing immediate answers to a certain number of puzzles). (Rigorous verification remains to be done.) This leads me directly to the next section.

Approaches

The objective of the scientist is to reduce environmental variability so as to approach the ideal of the controlled experiment. Then all the observed variability is attributable to management factors.

In economic research on African agriculture, the environmental factors loom very large, as we all know. Economists, like sociologists, anthropologists, and those involved in managing the fieldwork in development projects generally, work in situations where the farm or the farm household is the unit of observation and the most important sources of information are farmers. Gathering this information involves talking to farmers, and the wide degree of error involved in this process is too well known to waste words on here: Sampling and nonsampling errors abound, the questions and answers are often not interpreted correctly — without mentioning the possibility that the questioner has not asked the right questions in the first place, or asked them of the right people.[8]

[8] There is a whole body of literature in French on what actually constitutes the decision-making unit in African agriculture. The question has been much discussed by one of the agricultural research networks mentioned in Section IV.

In the experiment station of the physical scientists, on the other hand, the plot is the unit of observation and all necessary information comes from the soil, the vegetation, the air, the climate. They are secure in the knowledge that if their instruments are well calibrated and properly applied, they will register a high degree of accuracy in their results. Farmers are to be eschewed at all costs lest they jinx the readings.

My attention was recently attracted to an article in *Science* by Dr. Rattan Lal (1987), whom I consider (from reading his articles) to be one of the authorities on soil physics presently working in African agricultural research. The title was "Managing the Soils of Sub-Saharan Africa." This is an important subject, for we all know that African soils rapidly lose their fertility if they are mismanaged, and therefore soil management is critical to agricultural production. Yet it was not until the fifth page of Lal's article that I came across the first reference to the managers of these soils, that is to say, African farmers. The reference somewhat puzzled me, at that. It read, "The research findings on mulch are by no means new even to subsistence farmers." Surely Lal must be mistaken. He meant to write "The research findings on mulch are by no means new even to scientists at the International Institute of Tropical Agriculture." Since I am certain he intended no invidious comparison between scientists and farmers as a class, what he was saying was that scientists from IITA, which was founded in 1967, had at some time after this date observed the beneficial effects that farmers obtained by maintaining mulch caps on yam heaps or complete mulching with palm fronds in southeastern Nigeria. According to Lal, this mulching is a "common practice." Southeastern Nigeria, being densely populated, has been the home of farmers for centuries. The observed practice was new only to the IITA scientists.

In keeping with the model that treats farmers as exogenous, agronomic research is technique-oriented rather than problem-oriented. The usual practice in a paper written by the physical scientist is to start with natural resources (soil and water, principally) and to discuss the potential and limitations of these for agricultural production. Each physical constraint identified by the researcher can be met by some form of improved technology. Thus, soil and climatic constraints can be alleviated through land clearing and development, tillage methods, mulch farming, fertility maintenance, and irrigation. Crop yields obtained in experiments on plowed versus unplowed land, on fertilized *versus* unfertilized fields, and so on, are compared. Crop varieties that are found to do better than others in controlled experiments are selected, and so on. The farmer comes into the picture only by inference, as the crops and cropping methods recommended by the experiments are identified. Finally, research themes are brought out, to be diffused among extension agents (e.g., "no-till farming," "alley cropping," etc.).

The net effect of this technique-oriented approach is to focus attention on the yield gap between farmers' fields and experiment station results.[9] In Africa, this yield gap is obviously quite large, especially if yields are calculated by dividing total production of a particular crop by the total area that includes some of the crop, regardless of crop mixture, as is frequently the case. The statement reported in a recent newsletter, for instance, that 30 million hectares of vertisols and associated soils in the African semiarid tropics could benefit from watershed-based technologies developed at ICRISAT conveys an image of large unexploited potential (ICRISAT 1987: 1). The burden is on the farmer to take up these technologies. In the next sentence, however, the writer adds, almost as an afterthought, that while these soils are highly productive, they are also susceptible to erosion. So here is a constraint that was not taken into account. Effective conservation techniques are also required to make the already developed technology work in practice.

Economists have been very slow to reduce the degree of environmental variability in their research on African agriculture. It is only recently that they have begun to learn things about LRA that permit variability to be transferred from the environmental to the management side of the ledger. Economists may never reach the point of being able to run controlled experiments in LRA, but I think on the whole they have an enormous advantage over physical scientists in their approach to research in that their basic model, with its concern for the ways land, labor, and other inputs are used in production, makes them more problem-oriented than technique-oriented.

For instance, the farmer faces a problem of soil conservation, which he or she handles in such-and-such a manner (by mulching with crop residues, by planting maize between bananas whose broad leaves protect the soil surface from splash erosion, and so on). Sometimes the cropping mixtures are very complex. The farmer could save labor by using a donkey-plow, certainly, but this would necessitate planting all the crops in rows. Doing this would imply loss of effectiveness of conservation techniques. He or she might also have to eliminate some of the species grown in order to simplify, thereby losing valuable synergistic effects among different crops planted side by side. Rather than being the beginning of a rational system of using resources to best advantage within the constraints imposed by the physical environment (which it is in the physical scientist's mind), the "improved technology" constitutes in reality an enormous complication to the success of the farmer's problem-solving method. The economist accepts as intuitively plausible the proposition that there is a reason for everything the farmer does, otherwise

[9] Herdt (1986) has shown that "yield gaps" persist even today in American agriculture.

it would not be done. Yet, methodologically speaking, we only see the reasons if we start with the problem and end up with the technique, rather than vice versa.

Methods

What does this difference in approach between the physical scientist and the social scientist suggest in terms of research methodology? As an economist, let me make it quite clear that I am not advocating that physical scientists cease what they have been trained to do. I am only arguing that they should do what they are trained to do in a manner that takes into account some of the realities of LRA in Africa that we economists can perhaps see more clearly than they, even if we have a hard time grappling with them.

Let me give an example of what I mean and let's see what the research implications are.

More than a decade of working on Africa has inclined me to the view that conservation is a fundamental element of the production function of LRA, not something that can be dealt with satisfactorily by a technological solution separate from the problem of crop production. For the farmer, time spent on building and maintaining tied ridges is time taken away from planting, cultivating, and harvesting operations. Therefore, conceptually speaking, attempts to move directly from the question of the soil and its fertility to the question of crops is flawed. The right path is from the question of soil fertility through conservation to the question of crop mixture, with a feedback loop from crop mixture back to soil fertility. In other words, I think, on the basis of research results to date, that we can fairly treat soil fertility in LRA in Africa as endogenous.

For the purposes of research on sustainable crop output, therefore, the right question may not be, What is the best fertilizer dose to recommend for this crop? But it may be, What is the crop or crop combination that will use a given dose of fertilizer most efficiently? In other words, it is not the fertilizer dose that should be the variable of interest, but the crop combination.

Asking the right questions is a good starting point to overcoming the constraints to agricultural research in Africa. Unfortunately, this is not going to be easy. We (and I mean both economists and physical scientists) have a lot of mental deadweight to unload.

Take the way our research is organized. In good Western logic, the easiest way to organize agricultural research is by commodity. The colonial powers in Africa organized their research this way. They were mainly interested in the export crops and their improvement. When in the post-independence

period the international agricultural research centers came along, they followed the same logical organization. So we have today IITA working on maize, root crops, and cowpeas; we have ICRISAT working on millet, sorghum, and groundnuts; we have ILCA working on livestock; and so on.

Once organized in this way, the research community applies itself to developing high-yielding varieties of the crop or crops it is mandated to improve. Plant breeders naturally concentrate on breeding. They manipulate the genetic material, making crosses, looking at segregating generations in experimental plots, and measuring yields of derived fixed lines in trials on experiment stations. They reduce environmental variability to a minimum. They naturally overemphasize the raw-yield potential of the crop they are breeding.

The result of this process is a high-yielding variety of the crop which, along with the accompanying input requirements, comes to be known as the recommended "package." The success of the process therefore depends on how widely the "package" is adopted by farmers. In Africa, there is an almost continuous variability in farmers' fields in terms of soil fertility and the crop mixtures grown to influence it. Each farmer possesses a number of traditional "packages," consisting of upwards of a dozen different crops grown in mixtures of spatial interspersion and staggered growing seasons. In these circumstances, the standardization of a recommended package, no matter how "good" the new technology, proves virtually impossible.

We failed by a wide margin to appreciate the full extent of the problem in our 1981 report. There, we stated that the crop-specific approach of the international agricultural research centers "has resulted in no viable packages based on new crop technology, in part because of the intractability of the crop adaptation problem, in part because such packages need to be tailored to the labor scarcity conditions of African agriculture" (USDA 1981: 112-113). What we failed to realize was that the variability inherent in mixed cropping systems posed a much more nearly insuperable obstacle to research organized along crop-specific lines than either the crop-adaptation problem (which, after all, could be overcome given enough time and effort) or the conditions of scarce labor scarcity in African agriculture (which would be amenable to solution through labor-saving technology).

Igbozurike (1971: 529) wrote of this state of affairs some time ago. Unfortunately, his call for "unstinted research into mixed cropping," made in a geographical journal, went unheeded by both social and physical scientists. Actually, between 1930 and 1960, scientists at the Institute of Agricultural Research in Nigeria conducted over 300 experiments on crop mixtures. This work was not extensively reported at the time, and after 1960, the work of

the research stations in the colonial period fell into disfavor with African governments.

The message has got to get through to those responsible for planning and directing agricultural research in Africa. The ISNAR evaluation mission to Rwanda included the following recommendations in its report (ISNAR 1983: 12):

- The main concern should no longer be specialized research on the various crops and animals, aimed at stimulating the modernization of traditional agriculture through the development of varieties with a high genetic potential.

- Lessons drawn from past failures should persuade Rwandan agricultural research to study new targets and methods.

  First, in the future less work should be done on improving specific commodities by using individual disciplines alone, and more attention should be given to identifying and solving tangible development problems using the multidisciplinary approach.

  Second, the responsibility of agricultural research should no longer end with making recommendations for improved techniques for a given rural environment; it should go further to project and monitor the effects of the proposed changes. Straight transfer of even the most appropriate technology should not be the end of the line; the ultimate responsibility should be the development of a given agrarian system in its totality, as concerns both people and products.

What are the chances that the message will be heard this time? There are a few hopeful signs of changing directions in agricultural research in Africa. But there are many negative signs as well.

To take the example again of Lal's (1987) discussion of mulch farming, he writes of the difficult problem of keeping a cover on the soil in semiarid regions with a prolonged dry season and a large cattle population. Tree species can be grown to reduce the risks of soil erosion. Manure can be used in place of fertilizer. "Integrating livestock raising with tree crops and food crops is an important link in provided the needed diversity for an ecologically sustainable system" (Lal 1987: 1072). Soil physicists may be supposed to have a broader view of agricultural production than plant breeders specializing in one or two crops, since it is the same soil that nurtures food crops, pastures, forests, and export crops. But Lal's assumption seems to be that the wilful growing of trees, the use of manure, and the integration of livestock do not already exist.

Would it not be more rational for researchers in the physical sciences in Africa to spend their time finding ways to improve the profusion of traditional farming methods, rather than reinventing the wheel many times over from some mythical *tabula rasa*? Farmers have already done a large part of the work of innovation. Why is it that physical scientists make life difficult by proceeding backwards? This only limits the field of discovery, as well as that of application.

Conclusion

The Green Revolution in Asia represented a successful scientific experiment because the physical environmental targets were narrow. Rice was already grown in millions of hectares possessing good water control, and short-stemmed, nitrogen-responsive varieties merely took advantage of this environment. For wheat, Dr. Norman Borlaug and others consciously decided on an effort to strengthen the environmental control by promoting irrigation and good water control and narrowing the soil idiosyncrasies by addition of fertilizers. Furthermore, as numerous farm management studies in India and elsewhere have demonstrated, farmers found little difficulty in adopting the new "package," and found it profitable to do so. As a result, adoption occurred over a very wide geographic area. But the physical ecosystems remained circumscribed and quite narrow.

In Africa, the situation and its possibilities are quite different. The physical ecosystems in which agriculture takes place are very diverse, lessening the degree of environmental control that can be attained by plant breeders outside the immediate area of their experiment station. This diversity is due to the mixed nature of agricultural cropping practices, rather than to any unique character of African soils, vegetation, or climate. To claim that African soils, vegetation, or climate are somehow hostile to agriculture reflects simply a defeatist attitude that is alien to researchers. Farmers therefore have difficulty in replacing their present "packages" with new ones. Until lately, economists have not understood the reasons for this, and plant scientists have for all practical purposes have washed their hands of this phase of the problem.

It seems clear that research results based on a proper conceptualization of LRA in Africa can achieve growth rates of two to three percent per year. These are not quantum leaps in the growth of food production but, if sustained over the long period, are quite respectable. The image of stagnation in African agriculture is in any case disproved by the simple statistics of food production. Twenty-four of 26 sub-Saharan African countries registered positive rates of growth of total food production between 1977 and 1986 (USDA 1988). The two exceptions were Mozambique and Sierra Leone. With relatively little additional investment in the way of infrastructure, expen-

sive inputs, or high operating costs, growth rates of food production in all these countries can in all probability be improved upon.

This discussion should help highlight some of the barriers to agricultural African research. We should now have sufficient evidence to be able to overcome these barriers. The following observations may be useful.

- We must recognize, as scientists, that a problem of mental attitudes toward agricultural research on LRA in Africa exists and constitutes a major constraint to the achievement of meaningful research results.

- The starting point of research on LRA in sub-Saharan Africa should be the production functions of farmers at different levels of management. This will enable agronomic researchers to focus their efforts on improving farmers' yields rather than on improving potential yields of crops in an experiment station milieu. By *yields* I mean the total output from a given piece of land. Further research is needed on appropriate and useful aggregate measures of output of a given land area (weight, calories, value). Likewise, measurements of soil fertility need defining and standardizing. These research findings will lend weight to a production function approach to research. This is because the addition to total crop output and to conservation of resources should weigh more heavily as criteria in plant breeding decisions than yield, resistance to diseases and pests, or other characteristics associated with individual crops.

- Economists, for their part, need to view the production function of LRA as a two-equation function rather than a single-equation function, the dependent variables of these two equations being annual crop output and resource conservation. The appropriate shifter in this case is not technology embedded in particular crops or tools, but the organization of resources in production.[10]

- Calculating factor productivities can open up insights into ways in which resources can be used more efficiently in production. But the effort should not stop here. The economist's tool kit can be considerably expanded in this process of research and experimentation. Some potentially useful tools have been lying around for a long time. They can help us investigate meaningful relationships like that between land equivalent ratio and the number of crops in a crop mixture, and to look into the feedback effects of crop mixtures on soil fertility in both the short and long terms.

[10] A reorganization of existing resources in a community in the Great Lakes Highlands of Central Africa is documented as producing a 56 percent increase in total volume of output, without introducing new technology or damaging the resource base (Hecq 1958: 994-996). Not all cases of reorganization can be expected to result in output increases of this magnitude, but the example illustrates the potential.

- The methodology for identifying physical and biological constraints and proceeding toward meaningful research results follows from the above. The overall goal should be to improve farmers'"packages" of agricultural methods and inputs.[11]

- This sort of research leads to results that do not automatically favor the most advanced farmers or the most advantaged regions, as the results from research organized along commodity lines tend to do. We need to face up to the possibility that all the Gezira and Rahad schemes of the African continent have been pretty well developed by now, and there are few localities left where large-payoff responses to research on high-yielding monocultures can still be found. This is important from a development perspective because it is in the relatively disadvantaged areas where farmers farm by low-resource methods that most of the production takes place and that there is the largest potential for employment generation.

- Since such a research effort is likely to have to start with farmers, this implies the need to reorganize the research effort and its institutions along lines more suited to this purpose than the present organization.

- While it is true that Africa lacks financial resources,[12] there is no need to duplicate the Agricultural Research Service of the U.S. Department of Agriculture in every African country. One solution to the problem of developing "critical mass" in research is to form networks in African countries. Some of these already exist, in fact their number is quite large (Martin 1986). Continuity is important in intellectual efforts, especially where the constant improvement of a long-range research effort is at stake. Networks provide continuity.[13] In the development of Kitale maize, the parent seed may have come from Ecuador, but foreign researchers working *at the Kitale station* provided an indispensable element of continuity.

- It would be unfair to suggest that the only constraints to achieving agricultural research results in Africa stem from the mental attitudes of the researchers themselves. Clearly not. In countries where applied research results have been achieved, farmers and farm communities have

[11] In pursuing this goal, we must not lose sight of the fact that low-resource agriculture depends on internally available inputs. As we work to improve LRA, we must not put it out of the reach of farmers. What were "the decisive technical factors" in the success of Kitale hybrid maize in Kenya? They were simplicity and viability (Johnson et al. 1979: 11).

[12] And research staffs in "small" countries have to be as well trained as in large countries, as Ruttan (1982: 175) points out.

[13] I have been a member of such a network for a number of years, benefiting from exchanges of information and insights with my colleagues in African and other countries. I hope my membership has been beneficial to them as well.

usually been instrumental in supporting the research. We all know how, in democracies like the United States and India, such support comes through the political process. Legislatures ensure the financial wherewithal for the prosecution of agricultural research, albeit at the cost of exerting some measure of direction over the research.

- Farmers in Africa have many fewer means of exerting pressure for research work. It is significant that in the African countries where research has had the most successful record, like Zimbabwe and Kenya, the farmers (in Zimbabwe the commercial farmers) were the best organized politically. The governments of most African countries, while paying lip service to agriculture, are cut off from their farmers when it comes to deciding on the allocation of scarce budget funds. This is a strong reason why it is essential that applied agricultural research be organized as much as possible on national lines and involving nationals as decision makers.

- In concluding, let me recall an insight into the process by which people search for ways to improve agriculture. The agricultural geographer Pierre Gourou wrote that land use (and by extension we can say the use of all resources) is primarily the result of cultivating techniques and not of the physical environment. "Human choices have been influenced much more by the level of techniques than by physical conditions" (quoted in Nair 1983: vii). Gourou worked mainly with rice, a crop that is grown, as we know, in an extremely wide range of ecological environments, soils and climates. I see the observation of this great scientist as conveying a hopeful message, both to economists and to agronomic researchers working in Africa.

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DEALING WITH SIZE-CONSTRAINT STRATEGIES FOR TECHNOLOGY MANAGEMENT IN SMALL AGRICULTURAL RESEARCH SYSTEMS

Elon H. Gilbert and M. S. Sompo-Ceesay

Abstract

Investments in agricultural research can have significant payoffs for agricultural development. This has led donors to invest large amounts in agricultural research projects in third-world countries. Yet despite this major investment of funds, very few third-world countries, particularly in Africa, have been able to develop effective agricultural research systems. This limited progress can be traced in part to the absorptive capacities of national agricultural research systems (NARS) in relation to donor-funded projects and the difficulties that NARS have in reconciling broad research mandates with resource constraints, particularly manpower. This paper focuses on these issues in relation to the special problems of small developing countries, where an effective agricultural technology management system (ATMS) is even more essential in allocating very limited research resources. Concurrently, the dangers of major distortions in the research system from external support are generally far greater than with larger NARS. Small-country NARS tend to be thin/fragile, but an effective ATMS can turn this to advantage since the research system may be more receptive to change than larger systems.

Introduction

It is generally accepted that investments in agricultural research can have significant payoffs for agricultural development. However, few third-world countries have been able as yet to develop effective national agricultural research systems (NARS). The mediocre records of many NARS have given rise to doubts about the feasibility of creating self-sustaining and productive national agricultural research systems in many countries. Small developing

countries, in particular, are viewed as questionable prospects for the successful development of research systems. There is often insufficient manpower and other resources to mount what Ruttan (1987) has characterized as the "minimum national system."[1]

The focus of the following discussion is on the special circumstances that the group of smallest developing countries face in the management of the limited resources available for agricultural research. Treating small NARS as scaled-down versions of larger systems tends to avoid the hard choices that must be made to concentrate resources on a set of activities that are at the same time responsive to client needs and consistent with capacity. The initial section of this paper reviews the major distinguishing features of small NARS. This is followed by an examination of the implications of size for the choice of research topics and methodology. Special attention is given to linkages between the research system, its principal clients, and its sources of innovations. We conclude that small NARS are both desirable and feasible and offer recommendations for improving their effectiveness.

The group of smallest NARS that are the focus of this discussion have fewer than 50 person-years of scientists and total annual research budgets that are less than 0.5 percent of the agricultural gross domestic product, including recurrent and capital costs but excluding donor funding. Support costs per researcher are not necessarily a good measure of smallness since larger NARS may be able to operate quite effectively on lower figures because of scale economies. A small NARS may be formally responsible for a broad range of issues and commodities but may undertake substantive research on less than a dozen topics at any point in time.

In spite of the undeniable difficulties, all low-resource countries with serious agricultural development aspirations must have some mechanism(s) for identifying productivity-increasing innovations. Research, narrowly defined, is one such mechanism. The challenge for small developing countries is to identify mechanisms that do the job in a fashion that is consistent with their resource endowments. Only a limited amount of research, largely or exclusively adaptive in nature on carefully selected topics, may be all that is possible in small, resource-poor countries. This usually means that workable and sustainable mechanisms that rely heavily on external sources of information and expertise on the one hand, and on extension services on the other, must be developed. In short, the effectiveness of a small NARS may

[1] Ruttan's (1987) definition of small systems focuses upon population size. Small countries with populations in the range of 4 to 10 million generally have sufficient resources for developing viable agricultural research and training institutions. Ruttan (1987: 234-235) also feels that a capacity for degree training in agriculture "at least through the master's level" is required for viable systems. The focus of this paper is upon the approximately 50 lowest-income countries that fail to meet the minimum standards as specified by Ruttan

depend less on its ability to perform "research" than in its capacity to manage its own limited resources and mount collaborative efforts with other organizations, both external and domestic.

The failure of NARS, both large and small, is often traceable to shortcomings in the agricultural research management system (ARMS). To the extent that they function at all, the ARMS in many countries often fail to properly execute their designated functions; namely, to define and enforce research priorities in a fashion that is consistent with resource constraints and to program external assistance to create research capacity rather than exacerbating problems in already overburdened systems. The task is not only to identify which issues to focus upon, but also what kind of research can be successfully undertaken. The research agenda must be consistent with the constraints of the NARS as well as reflecting the concerns of its principal clients. In general, these constraints are not limited to small systems, but tend to be more binding in small systems and thus have a profound influence upon the character and magnitude of the research agenda.

Characteristics of Small NARS

A major distinguishing characteristic of a small NARS is limited resources rather than the size of the country it serves. For example, most Sahelian countries, regardless of their size, have small NARS. Although Senegal and Sudan have large systems by African standards, Chad, Mauritania, Niger, Mali, and Burkina Faso have small NARS in spite of the fact that geographically they are as large as, or larger than, Senegal. In contrast, countries such as Kuwait and Singapore can sustain relatively sophisticated NARS in spite of limited land area and agricultural potential.

Small NARS are usually young services in terms of the age of the staff and the institutions. In contrast to larger NARS which often had well-established research programs at the time of political independence, resource-poor countries often had little more than a substation of a regional research organization established by the colonial power. Resources devoted to research were concentrated in larger countries on commodities with high export potential. The limited tradition of research in small NARS adversely affects their status in the eyes of senior officials and potential entrants to the research services. It is not uncommon for a small NARS, just beginning to realize its potential a decade or more after independence, to be faced with a deteriorating economic situation and drastic cuts in public-sector budgets. Policymakers may be skeptical about allocating scarce resources to a NARS whose record of accomplishments is thin or nonexistant.

Institutional/Organizational Context

In The Gambia, research services are part of the Ministries of Agriculture and Water Resources/Forestry and Fisheries, rather than being autonomous or semiautonomous, as is often the case in larger systems. Table 1 shows the research staff and operating expenses of the Gambian Agricultural Research Services.

Table 1. The Gambian Agricultural Research Services (1987)

Department	Research Staff Nationals		Research Staff Expatriates	Operational Expenses[a]
	person-years			$
Ag. Research	17.5	(8)[b]	4.7	—
Livestock[c]	4.5	(2)[b]	1.2	—
Planning	1.0		—	—
Total	23.0	(10)[c]	5.9	212,500

[a]Excluding salaries.
[b]Staff in training are in brackets.
[c]Excluding national and expatriate research staff of the International Trypanotolerance Center.

Small NARS are part of government bureaucracies and as such are subject to the range of constraints normally found in such situations. The major characteristics of manpower, resources, management, and conditions of service are discussed in following sections.

Although there are many disadvantages to being part of the bureaucracy, there is also the advantage of closer institutional ties with the two main sets of clients — agricultural policymakers (including political leadership) and extension services. Senior ministry officials have a direct interest in research services. They also have supervision responsibilities over these services, so there may be more pressure to mount programs and produce results that will contribute to the realization of national agricultural policy objectives.

The linkages between research and extension may be stronger in small NARS since they both may share the same ministry or even the same government department. Once again, senior ministry and department officials may simply mandate collaboration even where subordinates may not naturally seek it, in contrast to large NARS which tend to be well-insulated institutionally from their principal clients in the government services.

As with larger NARS, research responsibilities may be divided among two or more departments/ministries. In The Gambia, research on crops is under-

taken by the Department of Agricultural Research, while research in socio-economics, livestock, forestry, and fisheries is the responsibility of four other departments which also undertake extension activities or special services in these areas. As already noted, such arrangements can facilitate linkages between research and extension, but the fragmentation of research capacity may diminish its status and prospects for making contributions, especially where research occupies a secondary or tertiary status in a department.

Manpower

Perhaps the most binding constraint in small NARS are the low numbers and skill levels of researchers. Full-time equivalents may be well under 50 person-years of research staff with at least first degrees. The number of full-time researchers is usually substantially less. Faced with broad research mandates, which may be similar in scope (on paper) to those of well-endowed countries, individual researchers with limited experience are given responsibility for a range of commodities/issues with little hope of adequate coverage. Teams of researchers working on a single commodity rarely approach the manpower requirements of the "minimum research module" of 12 researchers (four of whom should have higher degrees) which Trigo and Piñeiro (1984: 85) suggest is needed to carry out a reasonable applied-research program. One- and two-person research programs tend to be the rule. Researchers also commonly assume a range of management and administrative tasks and representational duties for the research program (attending meetings and preparing reports) which may leave little time for "research." The job descriptions of individual researchers might also include development responsibilities, especially where research services share departments with extension.[2]

The need for skilled research support staff is, if anything, greater than the need for researchers, especially in administrative and clerical fields. It should not be expected that the quality and quantity of support staff will be significantly better than that of the ministries and departments of which the research services are a part. Technical specialists to operate and maintain scientific equipment and computers are either rare or nonexistant.

Small NARS, particularly in Africa, remain heavily dependent on expatriate researchers and, in many instances, on research support staff provided by externally funded projects. As a consequence, the combined influence of

[2] Despite the possible negative impacts on the quality and quantity of research, there are good arguments for giving most, if not all researchers explicit responsibilities for developing research and extension liaison as part of their job descriptions, especially in a small NARS. As is discussed in the section on linkages, the collaboration of extension is essential in carrying out many research and prerelease testing activities, as well as ensuring the efficient transmission of the research results to farmers.

expatriate researchers and donor agencies is often substantial. Expatriate researchers are also important in larger NARS in several African countries (Kenya, Senegal, and Ivory Coast), but there are important differences in their roles. First, leadership at the national and station levels is clearly in the hands of national researchers in virtually all instances. Second, expatriate researchers in larger NARS tend to stay for longer periods of time as part of support agreements that are long-term in nature, unlike small NARS where two- to four-year contracts for expatriates are the rule. This is critical in terms of the quality and type of research undertaken by these researchers. Expatriate researchers in larger systems often provide valuable continuity in research activities in the face of frequent changes in national staff through promotions and long-term training.[3]

Conditions of Service/Incentives

Because most small NARS are part of a government ministry, they are also subject to the conditions of service/incentives that normally operate in government service. Promotions are often based on seniority or financial and supervisory responsibilities rather than performance as researchers. Promotion of researchers above certain levels usually means giving up technical work for administrative responsibilities. Salary grades may give little consideration to degree training above the Master's level.[4]

Resources

The research activities of small NARS are very susceptible to the vagaries of government fiscal and trade policies.[5] Periods of austerity or structural adjustment are common and impact heavily upon real levels of remuneration of research staff and the availability of fuel and other supplies essential for research. Regulations governing budgets and expenditures are cumbersome and generally ill-suited to support any activity with a rigid time table, such as field trials.

Many small NARS depend heavily upon a patchwork of external funding for operational expenses since government support is largely limited to salaries

[3] Expatriate researchers in larger NARS also played critical roles in the transition to independence in those countries where research systems were developed during the colonial period. As noted in the introduction to this section, this was not the case with most small NARS.

[4] It would be instructive to compare researcher salary levels in small and large NARS, as well as with their counterparts in governmental service and the private sector. We suspect that such comparisons would not favor the small NARS researchers.

[5] In small NARS in the Central American and Caribbean region, where a single commodity dominates both the economy and the research system of an individual country, there may be strong vested interests in preserving a concentration of resources on that commodity despite changes in government policies (D. Drga, personal communication).

and wages. Substantial amounts of researchers' time is devoted to securing and managing externally funded special projects.

The acquisition and maintenance of even moderately sophisticated scientific equipment is beyond the means of most small NARS. Such equipment may be provided by special donor-funded projects, but it often falls into disuse due to the lack of skilled operators, maintenance personnel, and spare parts.

Management

Many of the critical factors affecting administration and management services in small NARS have been noted above, including shortages of skilled staff, poor conditions of service, and irregular financial support. The style of management can be characterized as bureaucratic or hierarchical. The major burden of many administrative tasks fall on the researchers themselves. Station facilities are often shared with other services, resulting in tensions over chains of command and the use of resources.

The Role of External Institutions

The preceding discussions of manpower, resources, and management of small NARS illustrate the substantial influence of external institutions. External support for a small NARS may be dominated by one or two donor projects which, while simplifying management requirements, place these donor agencies in the position of profoundly influencing the research agenda in a fashion that may or may not reflect national priorities. In contrast, no single donor is likely to play a dominant role in a large NARS.

The small NARS do not receive a great deal of country-specific attention from international agricultural research centers (IARCs) in selecting innovations for national research and development programs. As noted by Ruttan (1987: 175), "collaborative efforts [between IARCs and NARS] tend to involve the strongest institutions and the leading scientists rather than those who have the greatest need." This problem and possible alleviating measures are examined in the following section.

Research Agendas, Methodologies, and Technology Management

The characteristics of the small NARS, and specifically the binding nature of the constraints facing these systems, have important implications for both the research topics selected and the type of research that is undertaken. The research agendas and methodologies must be carefully selected to give those concerned a reasonable chance of success. In this context, success is defined as the ability to complete tasks in a way that commands respect and

recognition among peers and produces results that are useful to clients. The latter implies research results that are eventually adopted by farmers and have a measurable impact upon agricultural production and productivity. Most small NARS have yet to prove themselves in the eyes of policymakers and the donor agencies who are the principal sources of support.

This section begins by examining the phases of the research process and the major research activities to identify those areas in which small NARS have a comparative advantage. This is followed by discussions of commodity spread and the criteria for selecting topics for on-farm and on-station research programs. The issue of appropriate approaches to on-farm research for a small NARS is examined. The section concludes with a discussion of the possible roles of external institutions, particularly IARCs and institutions in developed countries.

Phases of Agricultural Research

Figure 1 illustrates five phases of agricultural research. Phase V, which is basic research, and phase IV, which is basic and applied in nature, are likely to remain beyond the capacities of all but the most well-endowed NARS. These phases are being addressed by IARCs and institutions in developed countries, particularly in the cases of the more basic elements of phase V. Phase III (generation of technology) is not only the priority focus of efforts at the IARCs, but also the phase in which larger NARS can and do make significant contributions.

The aim of adaptive research (phase II) is to determine if and how selected innovations might fit into target farming systems.[6] The adaptation to location-specific conditions is normally done in-country, often with the participation of farmers and extension services. When such modifications are performed externally, the institutions involved should have sufficient information about the target systems so that innovations can be "made to order" as, for example, the screening of varieties for tolerance/resistance to specific pests and diseases. Much of the research carried out by small NARS will be of this character, especially during the early stages of development.

Phase II includes the process of selecting innovations developed externally for possible use in-country. Given limited domestic research capacity, most innovations selected will hopefully require little or no adaptation in-country. As will be argued later in this section, innovations for all but a few high-pri-

[6] Adaptive research should be distinguished from prerelease or field testing of innovations. The latter are commonly carried out by extension personnel to acquaint themselves and a select group of farmers with a specific innovation prior to its widespread dissemination. Research is not a primary objective of such testing, as is discussed subsequently

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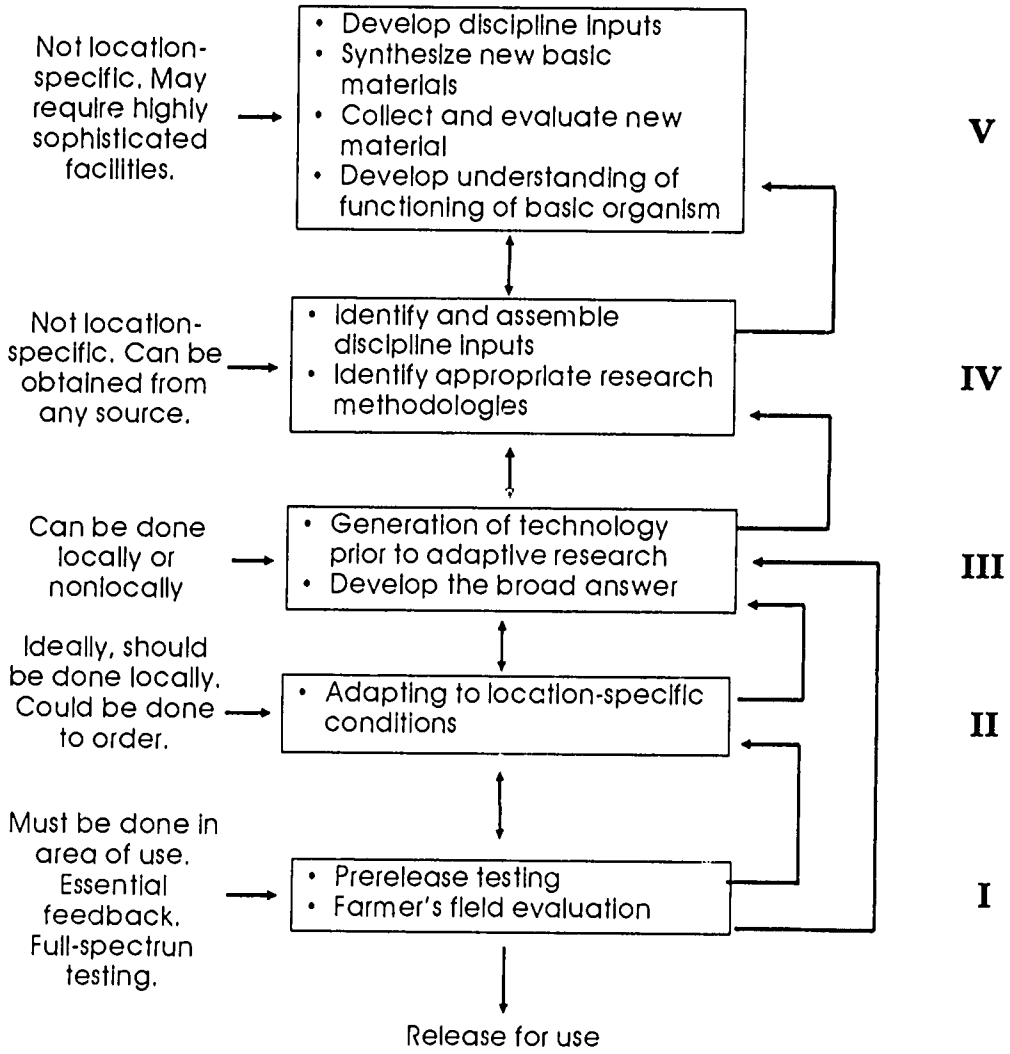

Note: Problem identification is a critical part of the "feedback" from phase I to phases II and III and thence to phases IV and V as indicated by the arrows at the righthand side of Figure 1.
Source: Diagram prepared by Howard Steppler and included in ISNAR (1981).

Figure 1. Phases of agricultural research

ority commodities must, of necessity, pass directly through to extension services for field testing, with minimal research input beyond the initial selection process.

As its capacity increases, a small NARS might conduct applied research (phase III) on issues critical to development efforts where there are compelling geographic or ecological reasons for carrying out the research in a

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specific location. Even so, most applied research requires a continuity of effort and experienced staff that are beyond the capacities of most medium to small NARS. Such undertakings are probably best left to the IARCs or special regional programs, possibly in collaboration with the local NARS. There is, however, a danger that the presence of such a program (or programs) will distort research priorities and resource allocations in a small NARS, including drawing off the most able research staff and support personnel.[7]

The prerelease testing and farmer evaluation of innovations (phase I) is a critical function that can only be done in-country, on-farm, and which is ideally carried out in collaboration with researchers, extension workers, and farmers. For many, if not most, innovations, prerelease testing may constitute the only "research" that is performed in-country. As will be argued in more detail later in this section, prerelease testing can assume greater importance than adaptive research (phase II) in the group of smallest NARS.

The Major Activities of a NARS

The range of responsibilities of a NARS can be characterized as a spectrum extending from contacts with sources of innovations (IARCs, NARS in other countries) and policymakers to research/extension liaison and pilot promotional activities. A 1987 report by the Special Program for Africa Agricultural Research (SPAAR) includes the following major activities of an agricultural research system (ISNAR/SPAAR 1987: 10).

1. Activities involving external linkages:

    a. searching world sources for information and materials that could be useful for national agricultural development;

    b. executing collaborative programs with other national research and academic institutions, including those in other developing countries and international agricultural research centers, to take advantage of existing information, methodologies, and materials;

    c. importing technology and adapting it if necessary to the needs of agricultural producers.

[7] The establishment of the International Trypanotolerance Center (ITC) in The Gambia is a case in point. There are sound ecological reasons for locating ITC here in terms of the range of tsetse challenge intensities and the presence of trypanotolerant breeds of cattle (Ndama). ITC and the Gambia Livestock Research Services are exploring areas of collaboration that could benefit both sides. The fact remains that ITC is likely to be the more attractive employer for the most able national researchers and research support staff.

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2. Domestic research activities:

   d. carrying out strategic and applied research to improve knowledge of the country's natural resources and their management and to generate new technology when imported options are not available;

   e. collecting, analyzing, and interpreting socioeconomic and agricultural production data and research results with a view to providing producers, policymakers, and planners with insights on the feasibility of various development options;

   f. maintaining permanent collections of plant and animal germplasm.

3. Activities involving linkages with extension agencies:

   g. developing linkages with extension services to jointly define farmers' problems and transmit appropriate solutions.

A small NARS is likely to devote a relatively large share of its limited resources to activities in groups 1 and 2 (external and internal linkages), in contrast to a more well-endowed NARS which might effectively sustain a range of activities in group 3 (domestic research). This difference is illustrated by Figure 2.

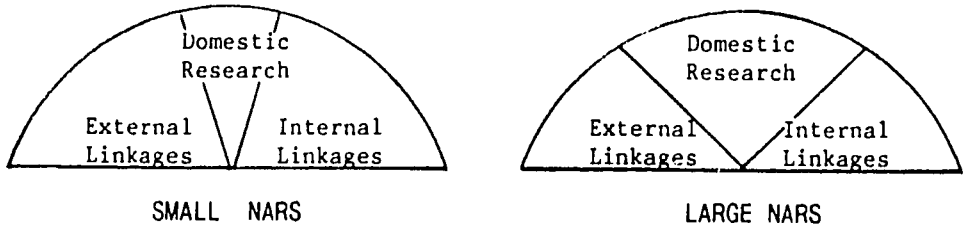

Figure 2. Resource shares devoted to groups of major research activities

Small NARS rarely have the capacity to attempt strategic or applied research aimed at generating new technologies (activity *d*) or to maintain permanent collections of germplasm (activity *f*), especially at the early stages of their development. Portions of activity *e* (collection, analysis, and interpretation of data and research results) should be given high priority and must be done in-country. Beyond collecting and performing routine analyses on agricultural statistics, small NARS are not likely to possess the capacity to mount

major surveys and in-depth investigations of farming systems involving substantial data collection and analysis. The utility of such major surveys is a matter of considerable debate. As much as possible, small NARS should rely upon rapid reconnaissance surveys to supplement the information available from existing agricultural statistical services. If a major survey is necessary, it is perhaps best undertaken in collaboration with an external agency that can assume the major responsibility for its execution. This would not preclude substantive participation by national researchers, particularly at the design and interpretation phases. Efforts to create and sustain an in-country capacity to mount large surveys can only be done at the expense of other functions such as activity *g*, for which the small NARS has a greater comparative advantage and capacity to carry out successfully.

Considerable time and resources of the small NARS should be devoted to external linkages (activities *a-c*). Priority should be placed upon identifying innovations that can be transferred with little adaptation. Ideally, such innovations would already have been successfully introduced to similar ecologies/farming systems. Such innovations have been referred to as the "low plums" — those that are ready for harvest and can be easily picked.

Since one farmer's plum may be another's lemon, thorough screening of innovations is essential. If anything, this process must be more selective for a small NARS than for a larger system, given its limited capacity to screen and adapt innovations internally. The identification of potential innovations requires both the capacity to interpret research results and, even more important, a good knowledge of the needs of the target farmers. This knowledge might come from in-depth field investigations (activity *e*), but as expressed above, the small NARS lacks the ability to undertake such research, except episodically and in collaboration with an external agency.

Linkages with extension services "to jointly define farmers' problems and transmit appropriate solutions" (activity *g*) is an area that should have priority in the small NARS. Information transfer in both directions is obviously critical to the process of defining research priorities and utilization of results. The fact that small NARS often share ministries or even departments with extension services can greatly facilitate such linkages but does not ensure their effectiveness.

Despite its importance, activity *g* often receives insufficient attention from the research side. Researchers argue with some justification that more attention should be given to producing research results, without which the linkages are meaningless.

Commodity Spread

Limiting the research agenda of the small NARS to a few priority commodities and issues is an essential, but extremely difficult, task. Policymakers and senior ministry officials are likely to be of limited assistance in establishing priorities and, instead, generally expect the research services to provide recommendations at short notice on virtually every commodity of importance in the country. The economies of small countries are frequently characterized by dependence on one or two export crops, and diversification is a major concern among policymakers and donor agencies. Accordingly, they look to the research services to provide information about all the commodities that *might* be successfully produced domestically.

Such pressures upon the research services are unavoidable. One possible approach to managing these demands is to designate all but a few priority commodities and topics as "minimum" or "zero" research areas. Innovations identified for possible use could be reviewed by researchers from the perspective of how they might fit into the target farming systems, but in most instances, no formal research would be undertaken in-country. Selected innovations would go directly to extension services for prerelease testing in the field. The involvement of the research service might be limited to assessing the results of the prerelease field tests of specific innovations in collaboration with the agencies involved.

The above suggestion shortcuts the normal research sequence and will inevitably produce a number of "misses." If development projects and extension services participate in the selection process and understand the risks involved, they are less likely to blame the research service when selected innovations fail the field tests. Simultaneously, the research services will be seen as responsive to demands for information in a fashion that does not critically dilute their research efforts.

The feasibility of the zero/minimum research approach is closely related to the capacities of development projects and agencies to carry out prerelease field tests of innovations with minimal guidance from researchers. Staff must have a good understanding of target farming systems. These are demanding qualifications. At the same time, the conditions of the small NARS may more readily accommodate the career aspirations of this type of person than a more narrowly focused researcher.

On-Farm Research

In spite of the extensive literature on on-farm research that has appeared in the past decade, the specific problems facing the small NARS have yet to be addressed. The thrust of the preceding discussions (and most references

to small NARS) suggest that on-farm research should represent a greater share of research efforts, compared to larger systems. Efforts, however, to introduce comprehensive on-farm research programs in small NARS, involving multidisciplinary teams devoted full time to on-farm research, often fail and are rarely sustainable. National researchers commonly have little experience with on-farm research and even less incentive to undertake it. Heinneman and Biggs (1985: 60-61) note that such efforts are often "top-down" in nature and fail to consider the constraints of the NARS itself, in direct contradiction to the guiding principles of farming systems research.

One major difficulty is the multiple responsibilities of individual researchers in small NARS. Quality on-farm research requires researchers who can make this task a priority. In one- or two-person research programs, it is not realistic or even desirable for a single individual to devote all his/her time to on-farm research to the exclusion of all other responsibilities. On the other hand, the linkages between on-farm and on-station research may be strong in small-NARS research programs because they are often carried out by the same person(s). External and internal linkages with IARCs, policymakers, and extension services (such as exist) may be strong for the same reason.

One approach used in The Gambia is to cluster on-farm research activities, including prerelease testing of innovations by extension services, in a few locations that roughly correspond to the major ecological zones of the country. The "cluster sites" facilitate efficient use of equipment and vehicles, and most important, make it more feasible for research staff to monitor prerelease tests (Posner and Kristensen 1987; Posner and Gilbert 1987).

As suggested earlier, extension services and nongovernmental organizations might assume primary responsibility for the field testing of innovations for commodities/issues that are not a priority of the research service. It is tempting to extend this argument to the complete range of on-farm activities. Extension personnel, however, rarely have the necessary skills and incentives for undertaking research tasks, especially where these are perceived as being primarily for the benefit of researchers. In the field testing of innovations carried out by extension, the research function is definitely secondary. Much can be learned from such testing, and researchers can enhance this process by assisting with design and monitoring, but problems commonly develop where researchers attempt to superimpose formal research objectives on these tests. The primary function of field testing is to enable extension personnel to do their jobs better — to more effectively communicate research results to farmers. The test results may indicate little more than that the innovation in question is not worth communicating, but that in itself is valuable information.

It is our view that all researchers in a small NARS should participate in on-farm activities, but not necessarily in formal on-farm research. At a minimum, researchers should monitor the performance of the agricultural sector with respect to the commodities/issues for which they are responsible. In addition to participating in the design and assessment of on-farm tests of specific innovations, as noted above, they should follow the progress of associated promotional activities. In short, researchers should be sources of information for development projects and agencies on what farmers are actually doing, in addition to innovations that might be introduced.

Linkages with External Institutions

The preceding discussion in this section makes several references to the critical process of selecting innovations for adaptation and testing in-country. This process can be assisted by scientists in external institutions who are familiar with a particular commodity or research area. The small NARS, however, faces distinct disadvantages in this process. First, scientists from external institutions are unlikely to have anything more than a superficial knowledge of the conditions in a specific small country, while they may have considerable knowledge about larger countries. Second, the individual small-NARS researcher may be faced with the task of making selections across a wide range of commodities, disciplines, and ecological/farming systems (Javier 1987: 3). Third, the all-important personal connections between NARS scientists and their colleagues in international centers and developed-country institutions, weigh strongly in favor of the large, well-endowed NARS. As a consequence, those most in need of assistance in the selection process often receive the least (Ruttan 1982: 175).

The de facto bias in favor of larger NARS is understandable in that they often have clearer ideas of what they want, they have the capacity to make more effective use of the materials and information provided, and their potential impact upon agricultural development, regionally or even globally, is greater. These considerations affect the decisions on research priorities made at the IARCs, and they should. The general failure of IARCs (and institutions in developed countries concerned with agricultural research and development) to develop strategies specifically to serve the small NARS is less understandable.

With the notable exceptions of ISNAR and WARDA, which are currently evolving strategies for serving the small NARS, no other IARC to our knowledge has faced this issue squarely (Javier 1987; Gamble and Trigo 1985; WARDA 1988). Commonly, the problem is defined away by saying that the small NARS is like a region or substation of a larger country. This ignores the fact that researchers at the regional and substation level in a large

country do not normally interact as directly with the external sources of innovations as do their colleagues in the small NARS.[8]

In our view, the problem is real and can be addressed without major changes in resource allocations and priorities at the IARCs (although that should not be ruled out). First, each small NARS should identify one or two individuals at each of the IARCs with mandates relevant to its concerns and who are reasonably familiar with the farming systems of the country. The IARCs, in turn, might designate an individual scientist as a "resource person" for each small NARS or for groups of NARS that they serve. This need not be a senior researcher in all instances. The resource person would be responsible for becoming acquainted with the broad dimensions of the farming systems, development activities, and research programs in the specific country. The same person might make at least one trip a year to the country, possibly to coincide with annual research reviews, if such exist. The resource person would also serve as a contact point for researchers from the NARS desiring assistance from the IARC. Obviously, *every* contact need not pass through the resource person, but he/she can often be of considerable assistance in making the initial connections and in reviewing results (e.g., selections of innovations/planting materials) from the perspective of a greater understanding of the country in question.

Second, the small NARS should identify one or more individuals — preferably scientists at IARCs, large, well-endowed NARS in a nearby country, or developed-country institutions, who are willing to commit one or two months a year for several years to working with the small NARS. These external advisors might regularly participate in annual research-review and -planning sessions. In addition, they would offer suggestions on types of innovations to explore and possible sources of such innovations. External advisors could assist in making the necessary contacts and seeking support and technical assistance for specific undertakings as required. They might also offer suggestions on training opportunities for NARS researchers.

It is suggested that donor agencies give serious consideration to funding such associations as part of their bilateral assistance programs with small, low-resource countries. Such associations might be expanded to several scientists at the same institution, possibly as a backstopping component of a project to assist a small NARS. During and after the project, which might be implemented by a developed-country university or research institute,

[8] Some regional organizations, including the Inter-American Tropical Agriculture Center of Research and Training (CATIE) and the Caribbean Agricultural Research and Development Institute (CARDI), have attempted to serve groups of countries which include several small NARS. This is an attractive approach to bridging the gap in theory, but the results as well as the viability of the institutions themselves often leave much to be desired (Ruttan 1982: 174).

backstopping services could be provided to the small NARS on a continuing basis.

A major source of innovations in nearly ready-to-use form, can be large NARS in neighboring countries with similar ecological conditions. Communications, however, may be complicated by political and linguistic barriers, but investments in language training and visits to neighboring countries for researchers can yield substantial returns and should be included as components in projects supporting small NARS. Farmers themselves might be selectively included in visits to view promising innovations, especially where local languages suffice. Such contacts can serve to accelerate the farmer-to-farmer spread of new technologies across international frontiers, which are already an important source of innovations for many farmers in small-NARS countries.

These suggestions are not new, and examples already exist. Once again, however, the larger NARS tend to be the principal beneficiaries rather than the small NARS. Special commodity, discipline, and topic (e.g., animal traction and farming systems research) networks do perform valuable services by disseminating information and materials on specific subjects, but small NARS tend to be among the poorer users.[9]

Ultimately, the effectiveness with which small NARS use external sources of innovation will depend on what they can do for themselves. More of the time of senior researchers must be devoted to systematically sifting through the considerable information available and conferring directly with contact persons and others at external institutions. Contact persons and external advisers, as proposed above, can facilitate this process, but the decisions must be made by small-NARS researchers themselves. The linkages with external sources of innovation should be made an explicit responsibility in the job descriptions of researchers, which in effect, means some reduction in the emphasis placed on performing research in-country.

Concluding Observations

This paper has focused on the characteristics of the small NARS and their implications for technology management. We started with the premise that all countries seriously pursuing agricultural development require some mechanism(s) for identifying productivity-increasing innovations appropriate for the target farming systems. Most small NARS are commonly young and resource poor and have yet to prove themselves to their principal clients

[9] One example of an information network is Rohdale International, which has recently initiated a newsletter "Entre Nous" to serve francophone countries in West Africa.

and sources of financial support. The imbalances between research mandates and capacity leads to a few researchers allocating their time to a broad range of issues and commodities. The low degree of task differentiation, however, both within the NARS and between research and extension services, could be used to advantage to form strong linkages.

As a consequence of resource constraints, small NARS must make careful choices among research priorities. Most research will depend heavily upon the availability of suitable innovations from external sources which require a minimal amount of adaptation. Unfortunately, small NARS are at a disadvantage vis-a-vis the larger NARS since scientists in external institutions are generally less familiar with conditions in small countries, and individual NARS researchers are required to select a few innovations across a range of commodities and disciplines. Few external sources of agricultural innovation have given explicit attention to the issue of serving the small NARS.

This paper offers suggestions for improving the process of selecting innovations through the use of external research advisors and resource persons at IARCs. More important, the small NARS must have a good understanding of its own farming systems. While comprehensive on-farm research methodologies are impractical, the monitoring of the principal farming systems should take priority in the allocation of resources for research.

Small NARS, of necessity, must collaborate with extension services and development agencies to achieve even a minimal coverage of their research mandates. Certain commodities and issues must be assigned a "zero" or "minimum" research status where researcher involvement is limited to selecting innovations developed externally for field testing by extension services. On balance, compared to larger NARS, small NARS should expect to devote a higher percentage of resources to external and internal linkages than to "research."

The success or failure of a small NARS depends heavily on its ability to define and enforce research priorities in a fashion that is consistent with resource constraints. Toward this end, governments and donor agencies should focus upon the development of strong agricultural research management systems and improved mechanisms for utilizing innovations developed externally.

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RESEARCH PRIORITY SETTING IN A SMALL DEVELOPING COUNTRY: THE CASE OF PAPUA NEW GUINEA

Jock R. Anderson, George Antony
and Jeffrey S. Davis

Abstract

Agricultural research in Papua New Guinea (PNG) has been evolving rapidly in the past few years, especially since the 1982 ISNAR review of food-crop research. New arrangements include segregation of the research activities on major export crops into industry-supported institutes and the concentration of government activities on foodcrop research. This context makes challenging a task of setting overall priorities for the nation as a whole. Notwithstanding these difficulties, an attempt is being made to establish a formal framework for improved decision making on investment in research in all the major commodities. This is being tackled in several ways, both from an aggregative commodity-oriented point of view using the Davis, Oram, and Ryan (DOR) model on economic surplus and trade, and a more micro approach based on subjectively elicited information on individual research projects conducted and being planned within the commodity-based institutes. The quantitative framework being developed should be useful to other small countries in the Pacific. Related projects on priority determination are under way in Indonesia, the Philippines, and Thailand. All these are being coordinated through ACIAR and ISNAR (in Indonesia).

Introduction

The project "Priorities for Papua New Guinea Agricultural Research Project" is financed by the Australian Centre for International Agricultural Research (ACIAR). Research is being conducted at the University of New England in cooperation with the Department of Agriculture and Livestock (DAL) in Papua New Guinea (PNG), as well as other government and nongovernment

instrumentalities in PNG, with the objective of providing assistance to decision makers on resource allocation to research.

Papua New Guinea — The Agricultural Base

Some 3.5 million Papua New Guineans inhabit an archipelago of half a million square kilometers. The livelihood of over 80 percent of the population is semisubsistence farming, based on shifting cultivation. Except for a few localities, there is no land shortage. Almost all land is traditionally owned, with a web of access rights regulated by custom. The country's traditional farming systems are just as complex, with tropical root crops, plaintains, sago, and local greens as the main staples. Pigs, the only significant traditional livestock, have been kept as a repository of wealth and used for customary exchange and feasts rather than as a regular food source, especially in the highlands region.

Plantations used to be the sole domain of introduced export crops such as coffee and cocoa. Smallholders' production for the market started with copra, but by now smallholders dominate the production of all export crops. The pace of social change is reflected in the rapid transformation of farming systems, demonstrating the resourcefulness of PNG farmers.

Developments in PNG Agricultural Research

Papua New Guinea experienced a colorful colonial history that features only modest levels of agricultural research until the post-World War I trusteeship administered by Australia. A strong, essentially expatriate research system that concentrated on export commodities was built up largely after 1950, especially in the 1960s, and flourished to the early 1970s. Independence in 1975 saw the start of many changes, as a program of "localization" of the public service was, rather belatedly, begun, notwithstanding the lamentable thinness of the indigenous cadre of agricultural technicians. This process has continued more or less steadily and, by the mid 1980s, expatriate managerial and scientific staff in agricultural research had dwindled to nearly a minority of a considerably reduced total. These scientists come from diverse nations (Australia, Chile, India, Uganda, the United Kingdom, and the United States. Most are employed on two-year contracts — an arrangement that, given the pace and gestation of most research, is not necessarily very conducive to high research productivity.

The PNG agricultural research system was substantially reorganized in 1986-87. Commodity-specific research institutes, associated with their respective commodity boards, are now responsible for the most important export commodities. Previously these were researched by multicommodity

government institutes. The new institutes are the Cocoa and Coconut Research Institute (CCRI) and Coffee Research Institute (CRI). Tea research has been terminated and rubber research has been left within the public domain but is moribund. The export-commodity research institutes have been given an initial government grant in the form of buildings and equipment and continue to receive part of their budgets from the government.

Only food-crop research effectively remains with DAL (fisheries and forestry are no longer under the jurisdiction of DAL and, at any rate, no research is presently undertaken in these). Following the 1982 ISNAR mission, food-crop research has been given a farming-systems research (FSR) orientation. Institutional reorganization has been completed, and FSR has commenced.

Technology-import activities at other sections of DAL could also be classified as adaptive research. In addition to the research activity of the national DAL, there are a few research establishments funded by provincial governments. Their work is, understandably, locationally specific. Some rural-development projects also have research components to assist their planning, decision making, and evaluation. Numbers of research scientists and 1989 budgets of the main research institutes of the country are summarized in Table 1.

Even though it has ceased to be explicit, the in-principle decision problem of allocating resources among commodities at the national level persists. However, as institutionalization of project results can only be done by practitioners, institutional changes in PNG necessitated that the tactical

Table 1. Research Scientists and Budgets at Main Agricultural Research Institutes in Papua New Guinea (1989)

Institute	Scientists	Budget
	No.	*US$ millions*
Export-commodity institutes	**27**	**4.7**
Cocoa and Coconut Research Institute	9	1.5
Coffee Research Institute	13	2.6
Oil Palm Research Association	5	0.6
DAL institutes[a]	**30**	**2.5**
Total	**57**	**7.2**

[a]The DAL institutes include the following: the Highlands Food Crops Research Team, Lowlands Food Crops Research Team, Agroforestry Research Station, Lowlands Agricultural Experiment Station, and Horticultural Research Station.

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objectives of the project recognize that, instead of a single national decision-making body, the present target audience is quite fragmented.

While the size of the task of supporting decision making by the national administration has been reduced somewhat, a new target group has emerged, namely, the decision-making bodies of the export-commodity research organizations. At their level, decisions are no longer involved with priority setting among commodities; rather, the commodity research organizations are only concerned about resource allocation within their own commodities — taking the analysis down to the level of individual research areas and even specific projects. Since these institutions are directly answerable to their respective commodity boards, commercial pressure results in an incentive to maximize perceptible returns to research. A corresponding allocation of resources to options with higher expected commercial payoffs is already being practiced at CCRI. Consequently, export-commodity research organizations are the project clients where institutionalization of project results can be expected sconest.

A similar target audience in the public system is the research administrators of research institutions, who have to draw up their research plans on the basis of expected funding and finalize their programs on the basis of actual funding. A more detailed economic justification for individual research areas or projects would aid planning and presumably simplify annual approaches for funding.

Research Objectives

The main purpose in the project is to produce a framework that (a) aids decision making about research priority setting and resource allocation and (b) is tailored to the conditions of PNG. The framework being developed is not intended to be used as the ultimate authoritative guide to the relative worth of research options. Rather, it is to be an indicative aid to decision making and a way of aiding systematic thinking about the planning of agricultural research in an environment of scarce resources.

In contrast to the commodity-regional DOR study, the main research categories serving as the options considered in this study are research areas within commodities, representative projects, or an amalgam of projects within a research area. This is because of the necessity to cater to the needs of research administrators dealing with the problem of priority setting for work on one or two commodities. In addition, on the basis of interviews with the scientists involved, such research entities are the highest levels of aggregation of research about which research scientists themselves are readily willing to make judgments. Once the framework is adopted by a

research institute, the analysis can be extended with relative ease to provide a more thorough coverage of research options.

The expected costs and results of individual research projects for a commodity can be perceived as coordinates of discrete data points on its research production function. If the data loci are regarded as reliable enough and their number as sufficient, one can attempt to construct the function, or a section of the function, building on this information.

In terms of the spectrum of approaches and models surveyed by Anderson and Parton (1983), the idea of implementing a somewhat sophisticated and information-intensive aid to research planning may perhaps seem to be rather expensive, if not even analytical overkill, for a nation the size of and at the stage of development of PNG. A rationalization could be that most of the costs of such an effort are setup costs and, since this overhead is being provided largely as external aid as part of a larger research endeavor, the real costs to PNG of maintaining the framework as an on-going aid to planning are, in fact, quite modest, and thus it may well be quite a cost-effective instrument. Only with experience yet to be realized will the hypothesis implicit here be able to be addressed.

Modelling the Innovation-Adoption Process

Some of the assumptions of the DOR framework will be replaced by judgmentally tuned expected values. The innovation-adoption process has been characterized with the following parameters by DOR:

1. research and adoption lag (from the initiation of research to the adoption of new technology: assumed to be 11 years for all commodities);

2. probability of research success (referring to a five percent reduction in unit costs, on the basis of a unit research expenditure: estimated);

3. ceiling level of adoption in the region of research (estimated);

4. spillover lag to similar agroclimatic regions (assumed to be four years for all commodities);

5. probable extent of spillover without adaptive research (estimated).

As used by DOR, the probability of research success refers to a predetermined level of unit-cost reduction and a unit level of research-resource use. The former implies an all-or-nothing type of research outcome. The latter raises the question of the research production function itself.

Agricultural research in PNG is mostly of an applied nature. As such, it is not so much aimed at basic scientific progress as the improvement of some continuous quantitative or qualitative characteristics of the commodity in question. Scientists' estimates about the expected yield-increasing and/or quality-improving effects of the research, adoption rates, and spillover rates are employed.

Quantitative Framework

The quantitative method proposed for the PNG country study can be seen from the perspective of developments of the past decade or so in the economic evaluation of research through economic surpluses. The study of Lindner and Jarrett (1978) marked a new stage in addressing this issue. While the ensuing theoretical debate continued (Rose 1980; Wise and Fell 1980; Lindner and Jarrett 1980), Edwards and Freebairn (1981) worked on an ex ante application of the notions in the form of a trade model. Edwards and Freebairn (1982, 1984) further elaborated the model. A cardinal contribution of the related later work by DOR was the introduction of the notion of research spillovers and the incorporation of these in a quantitative multi-country framework.

The quantitative analytical process of the ACIAR priority exercise can be summarized in a simplified algorithm. The algorithm does not contain the following data for each country and commodity: (a) quantities produced, (b) quantities consumed, (c) elasticities of supply, (d) elasticities of demand, and (e) domestic price. Additional data came from the assumptions listed.

The DOR algorithm is approximately as follows:

1. Select the set of commodities to be studied.

2. Select commodity *i*.

3. Identify ecologically homogeneous regions (EHRs).

4. Select EHR *f*.

5. Identify countries belonging to EHR *f*.

6. Select country *y*.

7. Estimate the expected probability of research success and the ceiling level of adoption.

8. Estimate the expected rates of research spillover into other agroclimatically similar zones with and without adaptive research.

9. Calculate the new equilibrium price and quantity.

10. Calculate producers' and consumers' surpluses at both the initial and new equilibrum points for the observed period.

11. Calculate the present value (PV) of the summed changes in producers' and consumers' surpluses.

12. Repeat (7) through (11) for country $y + 1$.

13. Repeat (3) through (12) for commodity $i + 1$.

14. Tabulate results by commodity and country groups.

A fifteenth step in applying the DOR approach is to develop an information system in which insights and data from step (14) are embodied and through which decision makers are assisted.

An algorithm proposed for the PNG country study is presented to indicate the shifts of emphasis, compared with DOR. Data derivation is not shown, but apart from market parameters, the new collections of primary data required include the expected cost and expected length of each research project, the expected yield and price effects of new technologies together with the lags to adoption, the patterns of adoption and their life expectancies. Once these data are elicited, the algorithm proposed is

1. Identify a feasible set of commodities and research options.

2. Select commodity i.

3. Select research option j.

4. Generate a supply function from initial equilibrium price and quantity, minimum production cost, and elasticity of supply.

5. Estimate the extent, ceteris paribus, of vertical (price axis) supply shift (k) resulting from the adoption of the new technology.

6. Generate the shifted supply function from the initial equilibrium function, shift parameter k, and the nominated shift type.

7. Nominate the demand curve, and handle any research-induced shift.

8. Calculate the new equilibrium price and quantity.

9. Calculate producers' and consumers' surpluses at both the initial and new equilibrium points, for the observed period.

10. Calculate the present value (PV) of the summed changes in producers' and consumers' surpluses (gross research benefits), PV of research costs (RC), PV of net research benefits and internal rate of return.

11. Repeat (4) to (10) for research option $j + 1$.

12. Rank research options.

13. Define a type of research production function for commodity i by summarizing the data in (12), perhaps by an envelope relationship.

14. Repeat (3) to (13) for commodity $i + 1$.

Analogous to the fifteenth step in the DOR approach, the data can then be presented in informative ways. If all goes well, it may even be possible to define a research-efficient set and an optimal portfolio.

Spillovers — International and Regional

The concept of spillover benefits extended and developed by DOR continues to play an indispensable role in the PNG country study, adapted to the different situation. A national research organization would usually be presumed to wish to maximize benefits accruing to the country; thus, international spillovers are not normally viewed as an objective. International spillovers are monitored in the PNG country study to some extent in order to identify their price effect on the country, but they are not counted among research benefits.

PNG agricultural research is generally of an adaptive kind, aimed at solving local problems through the use of fairly standard methods. (Examples range from the chemical control of coffee rust, to breeding cocoa hybrids, to researching oilpalm nutrition.) Most new technology is likely to be highly specific to PNG, and in fact, there is probably little scope for spillover. In the present study, the notion of spillover is applied primarily to spillovers within the major PNG agroclimatic regions. The spillover mechanism constitutes a following process:

1. Identify the provinces belonging to the same agroclimatic zone as the province from whence the new technology is assumed to originate.

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2. Generate the supply function from the initial equilibrium price and the locally relevant quantity, minimum production cost, and elasticity of supply.

3. Determine the new world-market equilibrium on the basis of expected international spillover effects.

4. Estimate the vertical supply shift (k) resulting from the adoption of the new technology.

Some Expected Problems and Planned Extensions

The public-sector component of PNG agricultural research is being given an increasingly strong FSR orientation. This radical departure from procedures the of even a few years back will pose difficulties for the present analysis. Two of the most pertinent problems in dealing with subsistence foods in the present context are (a) quantity measurement and (b) pricing.

There are serious gaps in the knowledge about many of the country's unique ecosystems. Appropriate aspects of these have to be researched as an integral part of many research projects aimed at such things as directly increasing the yield of cultivated crops. Maintenance of seed gardens and continuous monitoring of potential breeding material are indispensable for any effective breeding program. The inclusion of such research in the proposed framework is important: the costs of basic/background research should be apportioned to those areas of the particular applied-research program that use its results. Empirical difficulties with this approach are that (a) there is bound to be more than one user of such research results and (b) a long period of time may prevail between the background research and the first identifiable user.

The main priority-setting procedure proposed is a "bottom-up" type. The establishment of priorities is made largely on the basis of the expected financial performance of proposed research projects. If wider national goals are to be reflected, these should act as further criteria for choice in addition to any more narrowly conceived financial accounting.

Data are being collected in such a way that the effects of new technology are predicted separately for smallholders and commercial producers. With the addition of similarly separated figures about their respective initial market equilibria, the expected research benefits accruing to both groups can be calculated. Explicit favoring of one social group over another, in principle, can be handled by appropriate weighting of benefits accruing to the respective groups.

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Conclusion

To follow recent institutional changes, the analytical and quantitative frameworks of the PNG country project need to be more than a mere adaptation of the DOR framework. This makes this country study more expensive than would seem to have been the case at first blush.

It is hypothesized that the implementation of the framework will be of benefit to PNG, in both economic and bureaucratic terms. It is also hypothesized that the framework will be adaptable and implementable at low cost to other small economies in the South Pacific. Both these hypotheses could, of course, be rejected. Whatever the outcomes may be, the experience will add to the sparse base of knowledge on the economics of formal planning of agricultural research in small developing countries.

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EVALUATING INSTITUTIONAL CAPACITY FOR AGROFORESTRY RESEARCH

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Abstract

Agroforestry can be defined as the intentional growing of multipurpose trees and shrubs in combination with crops, livestock, or other land uses for specific products (e.g., fuelwood, fodder) or services (e.g., organic soil mulch, shade). As a new discipline, agroforestry research faces serious institutional constraints: assigning responsibility for setting research priorities, organizing multidisciplinary research teams within and across discipline-specific institutional barriers, assigning responsibility for engineering integrated prototype systems from component research, and establishing exploratory on-farm research within station-oriented research programs. This paper describes the methods and organizational framework being used in the Agroforestry Research Network for Africa (AFRENA) by the International Council for Research in Agroforestry (ICRAF) to identify and overcome these constraints. Through AFRENA networks, ICRAF is trying to promote and support multidisciplinary, multi-institutional, client-targeted agroforestry research implemented in collaboration with national research institutes. The paper has three parts. The first reviews the institutional requirements for effective, technology-oriented agroforestry research. The second shows how ICRAF's approach of "Diagnosis and Design" is being extended to evaluate institutional resources and constraints to agroforestry. The third part discusses some of the institutional mechanisms that are currently being tested to overcome identified institutional constraints in different AFRENA ecozonal and national programs.

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Overview: The State of Agroforestry Research

Over the past decade, the level of national and international resources made available for agroforestry[1] research has risen dramatically and promises to increase steadily in the foreseeable future. This expansion, however, has been fraught with institutional problems, and subject to intense debate within the agroforestry research and development communities. The fundamental issue in this debate is the appropriate structure of research to generate agroforestry technologies that can be adopted by farmers through the burgeoning agroforestry extension movement.

The situation in the past decade has been quite polarized. On the one hand, increasing numbers of researchers in research institutions have become interested in agroforestry and have set up small research projects focused rather narrowly on specific scientific problems, often only obliquely related to practical problems and potentials in the field. On the other hand, there have been myriad agroforestry extension projects which — lacking any significant support from formal research institutions — initiated their own field research to generate and test agroforestry interventions, with results largely inaccessible to scientists outside the project

By contrast, a strong national agroforestry research system would be effectively and efficiently able to select research priorities; plan and coordinate research projects; implement on-station and on-farm research activities; design, test, and evaluate technologies with a network of farmers; and provide technical input into the policy and investment decisions needed to encourage farmer adoption of new agroforestry technologies. Such an agroforestry research system would be broadly defined to include all institutions involved in planning, implementing, or using the results of agroforestry research. But this ideal faces major institutional constraints. National leaders in agroforestry research and development need to evaluate the research system systematically. This must be done to identify ways of strengthening its capacity to address the special needs of agroforestry research, both as an integrated system and in individual institutions.

The purpose of this paper is to identify the special institutional factors that need to be present for effective agroforestry research, to provide a checklist

[1] *Agroforestry* is a collective name for all land-use systems and practices in which woody perennials are deliberately grown on the same land-management unit as crops and/or animals (either in a spatial arrangement or a time sequence). To qualify as agroforestry, a given land-use system or practice must permit significant economic and ecological interactions between woody and nonwoody components (Lundgren 1987: 48). By this definition, agroforestry includes a wide range of practices, such as alley-cropping, mixed intercropping of trees in cropland or pasture, rotational fallows using trees or shrubs, multistrata homegardens, border plantings of trees or shrubs adjacent to cropland, or understory crop production in forests or woodlots.

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of factors that can be explored in institutional assessment, and to review the common strengths and weaknesses of different types of institutions for agroforestry research. National agroforestry planners can use this rapid appraisal evaluation approach with key participants in the agroforestry research system as a tool in developing a program for national institutionalization of technology-generating agroforestry research.

Five Institutional Requirements for Effective Agroforestry Research

A review of recent experience suggests that a number of institutional factors have led to major failures or constraints in agroforestry research:[2]

- interinstitutional conflict or lack of coordination in allocating responsibility and resources for agroforestry research;
- lack of a development perspective in setting research goals and in the reward system for scientists;
- inadequate breadth of scientific perspective for evaluating and modifying integrated, multicomponent, land-use systems;
- research divorced from the realities, insights, priorities, and context of the eventual users of agroforestry, i.e., farmers and other land users;
- a conservative institutional environment that discourages the exploration and utilization of innovative approaches to the new types of research problems posed by agroforestry.

The checklist suggested here thus approaches institutional evaluation in terms of these factors: political coordination of the research agenda, a development focus in research, multidisciplinary coordination, an on-farm focus for research, and an environment conducive to research innovation.

This approach was developed in connection with research planning exercises for the Agroforestry Research Networks for Africa (AFRENA) in nine African countries: Burundi, Cameroon, Kenya, Malawi, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe. A variety of methods, approaches, and sources were explored. The suggestions presented in this paper are based

[2] The conclusions of this paper are drawn from a review of institutional experiences with agroforestry research in a wide range of countries. References to this material include: Beer, Borel and Bonneman (1989), Depommier (1988), Djimde (1988), Djimde and Hoekstra (1988), Kwesiga and Kamau (1989), Minae and Akyeampong (1988), Minae (1988), Mueller and Scherr (in press), Ngugi and Buck (1989), Rocheleau (1987), and Scherr (1987c, 1986a, 1986b, 1986c).

on this experience, although the specific, integrated, committee-based approach proposed was not tested (for agroforestry).

The proposed approach is one of rapid appraisal of institutions, implemented by an interinstitutional (or in the case of a single institution, interdepartmental) committee. This group evaluates the five key factors, as suggested below, using interviews with institutional managers and researchers and interviews with key public policymakers and potential/actual users of research results, supplemented by institutional documents and institutional reviews by ISNAR and other external agencies. A system of ranking is used to indicate whether a factor is strong (or well-institutionalized), moderately well-institutionalized, or weak and problematic. This approach encourages direct and joint participation of researchers and institutional managers in information collection and evaluation, as well as in the formulation of institutional recommendations. Identification of the different institutions involved in agroforestry research is the initial step in analyzing the agroforestry research system and needs to be done both at the national level and for important agroecological zones. This inventory should include the institutions involved in extension because their capacity and structure for dissemination of information and their own research activities should affect the type of agroforestry research done.

It may also be valuable to inventory institutions that influence general land use and rural-development policies in the country or region. A national commitment to agroforestry is commonly reflected in planning documents and may reflect likely decisions in resource allocations to research. Specific past and current decisions to develop tree nurseries, disseminate tree seed to land users, encourage the planting of individual trees through changed land-use regulations, and develop public promotion of agroforestry will influence the patterns of agroforestry research.

Table 1 lists institutions in which agroforestry research, extension, and land-use/rural-development policy may be found. The example of Kenya reflects a particularly complex institutional structure.

Political Coordination of the Research Agenda

Research coordination and priority-setting in agroforestry is crucially important for three main reasons: the plethora of research topics; the frequent need for multi-institutional collaboration, coordination, or approval to address particular research problems; and the need to coordinate investments in infrastructure required for farmer adoption of agroforestry.

Table 1. Inventory of Institutions in Agroforestry Research, Extension, or Development Policy (An example from Kenya, 1987)

Government Ministries

Ministry of Agriculture, Dept. of Soil Conservation (fruit trees)
Ministry of Livestock Development (fodder trees)
Ministry of Environment and Natural Resources, Dept. of Forestry (Rural Afforestation Extension Service)
Ministry of Energy and Regional Development (Kenya Renewable Energy Development Project, Kenya Woodfuel and Agroforestry Project)
Ministry of Science and Technology (Kenya Agricultural Research Institute, Kenya Forestry Research Institute)
Ministry of Planning and Finance
Office of the President (land-use regulations)

Rural-Development Projects

Turkana Rural Development Project
Baringo Rural Development Project

Other Public or Parastatal Research Institutes

Coffee Research Institute
Tea Research Institute
National Tree Seed Centre (part of KEFRI)
National Herbarium

University Research in Agroforestry

University of Nairobi
Moi University
Egerton University
Kenyatta University
Departments of agriculture, range management, forestry, land policy, natural resources, economics; soil science, agricultural engineering, horticulture, plant science

International Nongovernmental Organizations in Agroforestry Extension and Research

CARE International
World Vision
World Neighbors

National Nongovernmental Organizations in Agroforestry

Church of the Province of Kenya, Diocese Maseno and Kisii
Saradidi Project

Donor Institutions Promoting Agroforestry Research and Development

USAID, NORAD, SwissAid, SIDA, CIDA, DANIDA, GTZ

Private-Sector Agroforestry Research and Development Activities

Bamburi
British-American Tobacco, Ltd.

Note: Institutions should be identified as having national and/or regional mandates.

Why Is Research Coordination Essential?

The acceptance of agroforestry as a legitimate research focus, attractive to donors and politicians alike, has led in many countries to a debilitating "turf battle" among different research institutions. Because of the multidisciplinary nature of agroforestry (discussed below), it may be justifiably housed in any disciplinary organization. Where interinstitutional competition is the rule, agroforestry research efforts are commonly fragmented and uncoordinated, with inadequate information exchange among potentially interested institutions.

This is particularly problematic because of the dramatic imbalance between available research resources and the enormous number of potential agroforestry components and technologies. This bewildering variety of potential functions, components, combinations, and arrangements — and the often limited recommendation domains of specific technology designs — makes it essential to develop mechanisms for setting research priorities. ICRAF has developed an approach to setting national or local research priorities ("diagnosis and design"), based on systematic analysis and prioritization of (1) the needs of land users in different land-use systems and (2) the potential of different agroforestry practices for addressing those needs. A methodology for this exercise is described in Raintree (1987) and Scherr (1987a, 1987b, *in press* a).

This planning process requires multidisciplinary input and multi-institutional decision making about responsibility for different aspects of the research process. Take the example of contour hedgerows in cropland, using shrubs for fodder for dairy cows. The decision to carry out major research on this technology may require the agreement of the ministry of livestock development (which may have a potentially competing program to develop Napier grass strips) and the ministry of agriculture (which may be opposed to trees in cropland). Screening of shrub species for fodder may be carried out most efficiently by the university department of range management, using seed collected by the forest research institute. The testing of hedgerow technologies with farmers may be carried out most easily through an existing NGO dairy extension project, whose managers will probably want to be involved in planning the research if they are expected to test it later.

Other key areas for coordination involve planning research collaboration between different institutions, accessing and disseminating research and extension findings from other countries, and providing input into the planning of agroforestry support investments, such as MPT germplasm distribution systems, farmer training, marketing initiatives, etc., all of which are commonly in a very early stage of development.

Assessment of Research Coordination

How can these functions for integrated research planning for agroforestry be applied? How will decisions be made and implemented? One can evaluate four areas of interinstitutional interaction:

1. ***Decision making for coordinated research planning.*** The first focus is on existing processes for decision making and coordinated research planning for agroforestry. This is influenced by whether the agricultural, livestock, and forestry research institutions are functionally integrated and/or have institutionalized joint planning. Countries where all major land-use research programs are housed in the same institution have found it easiest to develop integrated agroforestry programs. The greatest difficulties are in countries where research activities are in separate institutions, under different ministries.

   In recent years national coordinating or steering committees for agroforestry have emerged in many countries. These have varying levels of integration, collaboration, and control over the different types of research and development institutions in their countries. Some key questions to ask in evaluating their effectiveness include the composition of the committees, frequency and attendance at meetings, authorization for making decisions for constituent institutions, and access to important decision makers.

2. ***Status of agroforestry research.*** A second consideration in judging the likely effectiveness of agroforestry planning is the status of agroforestry research. This can be determined from the research, funding, and staffing priorities assigned to agroforestry in different institutions and the history (and thus intern[illegible]upport) of agroforestry research.

3. ***Development perspectives in research planning.*** A third important issue is the integration of development and extension concerns in agricultural research planning. Aspects to evaluate include the quality and frequency of their interaction in planning with the research institutions, the extent to which they are consultative or joint decision makers, and established mechanisms for sharing information between research and extension institutions.

4. ***Experience in multi-institutional project implementation.*** There can be many logistic difficulties in managing multi-institutional research projects. When these are being proposed, prior experience and protocol should be evaluated in terms of effectiveness for decision making, budgetary control, assignment of credit for project results, and control over data release.

Technology-Development Focus

One of the most difficult issues in research related to land use in general involves the competing claims of either expanding the frontiers of scientific knowledge in the long term or generating practical technologies for the current generation of farmers. The problem may be simplified as one of the *audience* for research results. *Scientific* research has as its major audience other scientists; *technology-generating* research has as its major audience farmers or other land users, directly or indirectly through extensionists.

Why Is a Technology-Development Focus Essential?

In agroforestry, scientific research cannot be relied upon to provide immediate spinoffs in terms of technology generation. In large part, this is due to the complexity of agroforestry systems. Intensive studies of components (e.g., studies of MPT phenology, water-utilization, rhizobium interactions), while valuable in themselves, rarely lead directly to farmer recommendations. This is because the actual productivity of the system will depend upon too many other variables: tree spacing and density, configuration of trees and crops, management of trees and crops, etc. Also, the range of selection of appropriate species, as well as spacing and management, will be strongly affected by farmers' existing practices. Technology development thus requires a judicious effort to pull together scientific research results in a combination appropriate to farmers' conditions. This may require much less elegant types of research and experimentation and more on-farm research (with its greater difficulties in statistical rigor), which may make publication in research journals more difficult and/or require more time in field pursuits.

Assessment of Technology-Development Focus

Whether an institution is organized to support technology-generating agroforestry research can be determined by looking at several variables. The first is the actual mandate of the institution and its history of pursuing this mandate. Will the institution receive greater recognition or funding for solving field problems? Will their success be measured by the extent of farmer adoption or by international scientific recognition? (The second variable is the reward structure set up for scientists.) Is promotion based on journal publications and sophisticated research design or on whether farmers adopt the technology? How is promotion and recognition affected by participation in multidisciplinary research? By participation in on-farm research? If institutions seriously want to pursue technology-generating agroforestry research, the system of institutional and personal rewards will commonly need substantial modification.

Multidisciplinary Coordination

For agroforestry, multidisciplinary research is essential. It is important not only for good disciplinary scientists to participate, but also for them to interact closely. Take, for example, the knowledge that may be required to evaluate a multiproduct alley-cropping technology: expertise in seeds for identification and provision of suitable tree seed, expertise in forestry for tree establishment and management, expertise in soils for analysis of soil fertility changes in the alley-cropping system, expertise in animal nutrition to evaluate the fodder component of the system, economic expertise to evaluate the economic viability of the system, and expertise in social systems to evaluate household and community impacts and the constraints of introducing the new technology. At the same time, the design of practical agroforestry technologies requires the active integration of disciplinary information in the context of farmer requirements and preferences: thus the need for collaboration. A large full-time team is not necessary, but regular access to disciplinary expertise is essential.

Why Is Multidisciplinary Research Essential?

Bjorn Lundgren (1987: 43, 49) introduces a recent review of institutional aspects of agroforestry with the following assertion:

> [T]he main constraints to a full realization of the potential of agroforestry [are] of an institutional nature and related to the rigid disciplinary compartmentalization which characterizes institutions working in the field of land use. . . . agroforestry as a science and practice must cut across conventional institutional areas and draw upon several disciplines in the social, production and environmental sectors if its full potential for improving land use is to be realized.

Lundgren attributes this compartmentalization to historical factors separating land-use specialties between forest, range, and agricultural lands in the temperate regions (then borrowed by tropical countries) and an emphasis on land-use specialization in production and development. An additional barrier is created by differences in the training, interests, and perspective of researchers and those of extensionists, even within the same field.

Farming-systems research and training in many countries have encouraged a more integrated approach to identifying problems in farming systems. It has also led the way in exploring mechanisms for combining disciplinary expertise with a systems perspective. But these experiences also illustrate the kinds of institutional problems that can arise in organizing such research. Institutions must manage the psychological conflicts that arise from disciplinary chauvinism, and which are related to the lack of a common vocabulary and conceptual framework as well.

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Assessment of Multidisciplinary Resources

Evaluation of institutional capability for multidisciplinary research requires identification and assessment of the availability of multidisciplinary expertise, mechanisms for effective multidisciplinary interaction, existing programs of multidisciplinary research (including agroforestry), and curricula in leading university departments in disciplines related to land use.

In a rapid appraisal exercise, it is difficult to evaluate the effectiveness of multidisciplinary interaction, but a good sense of current problems and potentials can be gained by looking at existing resources and the level of experience in managing multidisciplinary teams.

Potential for multidisciplinary staffing. The first criterion for judging the capacity of national institutions for multidisciplinary research is the actual scientific staffing potential. In many countries, multidisciplinarity is seriously constrained by a shortage of scientists. This may be due either to institutional factors that restrict the hiring or promotion of scientists outside the principal discipline of the institution, competing professional opportunities, or an absolute shortage of trained scientists.

There are, of course, management options to address problems of shortages in particular disciplines. These include programs of advanced training, collaboration between institutions with different staff resources, secondment of scientists for special projects, etc.

Mechanisms for effective multidisciplinary interaction. A second focus of evaluation is on existing mechanisms to promote effective, harmonious multidisciplinary interactions. These include interdisciplinary training of participating researchers, mechanisms for sharing research results among component (disciplinary) and systems researchers, and clear guidelines for research responsibility and authorship of scientific papers.

Existing multidisciplinary research. A third criterion to assess is institutional experience in working through multidisciplinary research teams. The major places where this experience has been acquired are in integrated crop research programs, integrated rural-development programs, and regionally focused research centers. Experience in such projects may have influenced scientists' perceptions as to whether they will gain or lose status for being involved in multidisciplinary projects.

Interdisciplinary training. A fourth criterion to examine is the extent of interdisciplinary and farming systems training/experience of technical and social scientists. Scientists with a strong background in farming systems are generally much more proficient in carrying out land-use system diagnosis

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and agroforestry design. This integrated perspective is also encouraged when biophysical scientists receive broad agriculture/land-use training in their undergraduate studies, in contrast to those where disciplinary specialization began very early. A common constraint to successful agroforestry research is that while forestry expertise is often indispensable, forestry education is only beginning to include training in the agricultural sciences, farming systems, rural socioeconomics, and farmer communication.

On-Farm Research Focus and Integration with Extension

A strong on-farm focus is essential in agroforestry research. Indeed, the on-farm research component should be considered the central research activity in technology generation, the one that drives priority-setting in on-station experimentation. This contrasts with conventional agricultural research, where the on-farm component is usually secondary. This reversal comes about because the bulk of current data sources are found in existing agroforestry systems and because technology generation in multivariate agroforestry systems needs to be done in close interaction with the ultimate users. The major institutional issue is that on-farm research in agroforestry requires that researchers have access to communities and networks of farmers on a long-term basis.

Why Is a Focus on On-Farm Research and Extension Essential?

Because of the paucity of scientific data from formal agroforestry research in the past, agroforestry researchers must depend heavily on direct collection of information from existing agroforestry plots and from the experience of agroforestry development projects. Agroforestry scientists are in a position similar to that of crop scientists operating a century ago, who began work in little-explored fields by studying the practices of farmers who were getting better yields than their neighbors, and then taking those ideas to the research station, rather than vice versa. The development of agroforestry technology is still so young that farm-focused research probably offers more scope for impact than highly specialized station-based research.

This dependence on the field is evident in many areas of agroforestry research. Very few tree and shrub species used in agroforestry have been subjected to systematic breeding, so there is extremely high genetic variability in the germplasm. In many cases basic phenological and morphological data are unavailable. This not only makes it more difficult to draw definitive conclusions from on-station species trials, but again makes field operations away from the research station (e.g., seed collection, or observation and measurement of trees growing under different ecological conditions and husbandry) an important part of research (Huxley 1987).

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On-farm research in agroforestry will also include studies related to tree-crop management and technology testing. This may involve not only (or even primarily) experiments designed on-farm to test components and systems under on-farm site and management conditions, but also ecological surveys, individual and group farmer discussions, monitoring and evaluation of existing and introduced agroforestry management systems, and superimposed treatments on existing agroforestry plots (Scherr *in press* b).

On-farm research can play a well-recognized role in helping researchers know their client, incorporate farmer conditions into research projects, involve farmers directly in research and access useful indigenous knowledge, and evaluate farmer adoption (Merrill-Sands et al. 1989). The quality of multidisciplinary scientific interaction may improve by focusing the team's work on problem-solving for a particular group of farmers.

Direct collaboration with farmers also helps focus research on issues of technology design and problem solving. The design of any product is easier when the client is clearly identified and can discuss and evaluate design specifications directly (Rocheleau 1987). Interaction with farmers under field conditions is likely to lead to improved selection and implementation of complementary on-station experimental trials. It also exposes researchers to farmer-developed innovations (Atta-Krah and Francis 1987).

On-farm research can also improve research-extension-farmer linkages by offering a site where they can work together regularly. The process of translating research results through extension into sustained farmer adoption is greatly facilitated. This is so both because there has been early testing of technology under active evaluation and input from the eventual users (both extension workers and farmers) and because, through early and sustained interaction, the institutions develop more effective communication. Indeed, in agroforestry the lines between research and extension may be quite blurred. Researchers who work with networks of farmers for technology development will inevitably be drawn into some extension activities. Extensionists have an opportunity to exploit their everyday interaction with farmers (as well as with structured monitoring systems) to test and evaluate agroforestry interventions and their adaptation by farmers (Mueller and Scherr *in press*; Beer et al. 1989; Raintree and Hoskins 1988).

While these are strong reasons for emphasizing on-farm research in agroforestry, many institutional constraints face such a program. Not only are few research-sector scientists trained or experienced in on-farm research and extension, but many have been trained in a paradigm which expressly identifies the farmer, and usually even the extension agent, as playing only a passive role in receiving scientific results from researchers.

There are also logistic and administrative problems involved in multi-institutional on-farm research sites, similar to those for on-farm research on any topic, e.g., responsibility for farmer contact and organization, division of responsibilities for data collection and evaluation and coordination of extension and research inputs (see Merrill-Sands et al. 1989).

Assessment of On-Farm Agroforestry Research Capacity

In evaluating institutional capability for on-farm research, some of the information to be collected and assessed includes on-farm research experiences, institutional arrangements in existing on-farm agroforestry research, and governmental and nongovernmental agroforestry/tree-growing extension projects which could benefit from on-farm research.

Experience and attitudes toward on-farm research. The first criterion evaluated was the experience and training of scientists in on-farm research. It is important to identify the content of the on-farm research activities, for example, as among the following:

- objective to test new technologies under the biophysical conditions of farmers' fields and management practices or to encourage farmer input into the design and evaluation of new technologies;
- evaluation of farmers' existing practices, relative to the testing of new technologies;
- collaboration of social scientists with technical scientists in on-farm trials or in surveys of farming practices and constraints;
- assignment of on-farm research perceived as a promotion or demotion.

Experience with on-farm agroforestry research. A second factor to assess is experience with on-farm agroforestry trials and other types of on-farm research (e.g., surveys of local knowledge and use of trees and shrubs by farmers), also looking at the issues raised in the preceding section. These can be important training grounds for agroforestry researchers and will influence the direction of future research planning.

Involvement of development institutions in research. The third factor to assess is the potential for using development project sites for agroforestry research and technology testing. On-farm research is commonly constrained by the researchers' lack of experience and resources for organizing farmers effectively, developing reliable networks for provision of necessary inputs, negotiating the terms of trials with farmers, monitoring participant farmers frequently, etc. In many cases, it would be more resource-efficient to utilize

existing networks of farmer and extension workers in agricultural or agroforestry development projects, rather than initiating new, independent, researcher-managed networks. Such an approach also facilitates pilot extension testing of new technologies and early input of farmer and extension expertise in technology design. These projects must, however, be given a serious commitment to technology generation over the medium to long term in the research area, and they must be organized to permit systematic monitoring and evaluation of farmer adoption and practices.

Environment for Research Innovation

The need to encourage research innovation is, of course, not peculiar to agroforestry, but it deserves emphasis here because of the newness of scientific agroforestry. The lack of established methods and approaches is an important constraint to effective research. Conventional agricultural and forestry research methods are commonly inappropriate in situations where components are mixed, although they are the most acceptable to conservative research organizations.

Why Focus on Research Innovation?

There is potential for important breakthroughs in agroforestry through support of individual initiative and innovation. The body of scientific information about MPT species (even basic phenology, morphology, or treatments for seed germination), their interaction with nonwoody species or response to different management regimes, is very small. There is no standardized set of methods for assessing agroforestry components or systems. Indeed, agroforestry research only came of age after important methodological advances had been initiated in agricultural research related to intercropping, multiobjective and multiperiod analysis, and resource sustainability. We are still far from understanding how to handle these issues efficiently in most agroforestry systems.

We understand even less about the processes of farmer adoption, adaptation, and intensification of agroforestry systems. This makes it difficult to develop research strategies and priorities, and it again demands researcher innovation in approaching farmers' needs and collaboration.

Assessment of Institutional Environment for Innovation

Institutional characteristics affecting research innovation in agroforestry are little different those that affect other types of research. Innovation tends to be hindered where there is excessive bureaucracy, excessive resource limitations that restrict initiation of new experiments, an entrenched hierarchy, defensiveness about research topics, or rigid adherence to specific

methods and approaches. Individual scientists need to have some scope within the program or project structure to pursue unexpected findings, methods and opportunities.

These factors are difficult to assess in a rapid appraisal exercise, but indicators may be found by reviewing a list of research projects and by exploration of the process by which individual research projects originated.

Assessment of Alternative Institutional Arrangements for Agroforestry Research

An active debate is going on in many countries about where to house agroforestry research institutionally. In this section, we will review the different possible institutional niches for technology-generating agroforestry research, as well as their relative strengths and weaknesses (as commonly constituted) in terms of the five factors discussed above.

Institutional Models for Agroforestry Research

Four major groups of institutions can and do participate in agroforestry research: national research institutions, national extension institutions, independent research institutions, and development projects. In each group, one may find at least three distinct variants that imply different institutional arrangements for agroforestry. In addition, agroforestry researchers may be linked in various ways through formal collaborative networks that are either focused on special topics or are more integrated. Each of these alternatives is described briefly below.

National Research Institutions

Agroforestry research programs in national research institutions come in three forms. Independent or autonomous disciplinary research institutions are the most common institutional framework for formal-sector agroforestry research. Examples are the Kenya Forestry Research Institute and the Kenya Agricultural Research Institute, under the Ministry for Science and Technology. A modification allows for formal arrangements for joint research between scientists in different disciplinary research institutions or departments. A third model is the distinct agroforestry research institution or large-scale program for agroforestry research. Examples of such institutions include the Department of Agroforestry of Burundi's ISABU, the All-India Coordinated Agroforestry Research, and ICRAF itself (for selected research activities).

Table 2. Checklist for Evaluating Institutional Capacity for Agroforestry Research

Interinstitutional Planning and Coordination

Decision-Making for Coordinated Research Planning
- ☐ Integration of agriculture and forestry research institutions
- ☐ Coordinated planning of agricultural and forestry research
- ☐ Integrated research planning for agroforestry

Status of Agroforestry Research
- ☐ Agroforestry as a research priority
- ☐ Extent of past agroforestry research

Development Perspectives in Research Planning
- ☐ Integration of extension, policy, and land-use interests in research planning
- ☐ Mechanisms for linking research and extension

Experience in Multi-Institutional Project Implementation
- ☐ Management and budgeting
- ☐ Assignment of scientific credit, control, and data release

Development Focus in Research

Institutional Commitment to Development Focus in Research
- ☐ Institutional mandate for development-focused research
- ☐ Sensitivity of funding to development impact

Scientists' Commitment to Development Focus in Research
- ☐ Internal reward structure for scientists for development impact
- ☐ Prior experience of scientists in development programs

Multidisciplinary Research

Potential for Multidisciplinary Staffing
- ☐ Multidisciplinary staffing of research institutions/departments
- ☐ Type and number of biological scientists for agroforestry research
- ☐ Type and number of social scientists for agroforestry research

Mechanisms for Effective Multidisciplinary Interaction
- ☐ Interdisciplinary training for participating researchers
- ☐ System for sharing research results between scientists working on component and systems research
- ☐ Clear guidelines on authorship of scientific papers

Existing Multidisciplinary Research
- ☐ Existing farming-systems research programs
- ☐ Experienced multidisciplinary research teams
- ☐ Existing field sites with integrated multidisciplinary research

Interdisciplinary Training
- ☐ Interdisciplinary or farming systems training in agricultural education
- ☐ Interdisciplinary or farming systems training in forestry education

On-Farm Agroforestry Research

Experience and Attitudes towards On-Farm Research
- ☐ Tradition of on-farm trials/testing by research institutions
- ☐ Tradition of on-farm social science research
- ☐ Existing farming-systems research

Experience with On-Farm Agroforestry Research
- ☐ Experience with on-farm agroforestry experimentation/research
- ☐ Existing information on farmer use and knowledge of trees and shrubs

Extension Involvement in Research
- ☐ Tradition of on-farm trials/testing in extension/development projects
- ☐ Tradition of collaboration between research and development institutions
- ☐ Past collaboration between research institutions and extension institutions in agroforestry/forestry/tree crops

Research Innovation

Effect of bureaucracy and hierarchy on research planning and decision-making

Attitudes toward novel scientific methods and approaches

National Extension Institutions

Research programs in national extension institutions are the second major locus for agroforestry research. Again, there are three different institutional models. The first is the disciplinary extension institution which includes a research department or unit, such as Agritex in Zimbabwe. Agroforestry research tends to be focused on specific tree outputs or services considered a priority in the institution and in priority farming systems. A second model is the agroforestry institution or program that combines research and extension responsibilities. Such an institution will generally view agroforestry as a more integrated land-use approach and will work with a wider range of tree species for a wider range of uses and niches.

A third model is the integrated institution with responsibility for all aspects of rural land-use research and extension, including agriculture, livestock, forestry, and agroforestry. This is conceptually the most satisfying model for integrating agroforestry into national land-use planning and research. Such an institution would work on the basis of integrated land-use/farming systems analysis and the selection of the most promising interventions for each system among the disciplinary alternatives. Rivalries for resources and control, however, have so far prevented this approach from being widely adopted. In practice, even where a single ministry or regional development authority is given jurisdiction over development and research in agriculture, livestock, and forestry, there has been effective functional separation.

Independent Research Institutions

A number of research organizations are relatively independent of the pressures of national research or development policies in the selection and pursuit of research. These include much university-based research, individual scientists supported by independent research grants, and private-sector research institutions.

Much of the basic research in agroforestry found in the tropics has been carried out in universities, and there is a growing body of thesis literature that has been largely untapped by the agroforestry development community. Such research is found in a very wide range of departments, including agronomy, range management, agricultural engineering (for soil conservation), plant science, natural resource management, forestry, agricultural economics, and land-use policy. Projects are mainly small, and experimental work is nearly always carried out on university research stations.

A second model is the "independent" researcher, who may or may not be university-based, but whose funding has been provided on an individual basis, rather than as an institutional project. Some members of the research

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community contend that bureaucratic approaches to research planning and implementation are contrary to the flexibility required for scientific innovation and discovery. Thus, many research organizations and donors operate on the basis of research grants or budgets tailored to individual scientists, rather than to "priority" topics per se, on the hypothesis that committed scientists must be allowed to follow their own direction and have the opportunity to work with limited constraints from existing policy, extension preferences, etc. Where research coordination, extension linkages, or multidisciplinary consultation are desirable, it is assumed they can be achieved informally or through separate grants for workshops and conferences.

This approach has been losing ground, with increased emphasis by national and international research policymakers on targeting priority research objectives for a coordinated push on key land-use problems. Nonetheless, a number of organizations that place a particular premium on scientific innovation channel much of their funding in agroforestry to individual scientists. Projects must still be carefully justified by the scientist as relevant to a general priority problem, but once they have been justified, the scientist is granted substantial scope for independence. These organizations include, among others, the Nitrogen-Fixing Tree Association (NFTA), the Board on Science and Technology for International Development (BOSTID), the International Foundation for Science (IFS), the Ford Foundation, and the International Development Research Centre (IDRC) of Canada. It can be argued that in a relatively new field like agroforestry, it is particularly important to reserve a role for such innovators.

The third group of independent researchers is found in the private sector. They now play a minor role in agroforestry research but have the potential for making important contributions in the future, particularly with increased commercialization of tree products from agroforestry systems. While there is an interesting array of small private research projects undertaken by individuals commitment to natural resource conservation (e.g., Bamburi quarry reclamation in Kenya), most efforts are commercial. Examples include efforts to develop agroforestry systems for production of fuelwood for tobacco; studies of tree leaf fodder; commercial testing of little-known indigenous tree species for wood, fruit, pharmaceuticals, resins, or other products; and organizations of larger-scale farmers in certain areas who sponsor research on incorporation of trees in pastures, or tree-derived feed for feedlots. The focus and resources provided to researchers in these settings can provide high-quality applied research.

Research Based on Development Projects

In the conventional model of agricultural research, new ideas are generated by research scientists, tested on-station, then in on-farm trials, then re-

leased to extensionists for pre-extension testing and modification, and finally large-scale extension to farmers. This model is inappropriate for many types of agroforestry research. Information on and experience with agroforestry practices and technologies is currently concentrated in indigenous farming systems and in projects of agroforestry extension. The latter are commonly initiated before reliable research results have been generated regarding effective and appropriate technology design and management. Indeed, the fourth important locus of technology-generating agroforestry research is in the context of local or regional development projects, where most experience in agroforestry research has been generated in the past decade. Three models may be identified.

The first model is the extension project with its own research component. Because of the general paucity of agroforestry research, researchers in projects that involve testing and improving interventions are forced to develop their own research programs. A survey of over 100 extension projects undertaken by ICRAF in 1988-89 found that over 80% were involved in technology evaluation, including research plot, on-farm species, and technology trials; field and farmer surveys to evaluate technologies, etc. (Mueller and Scherr *in press*). Some examples include the Nyabasindu Project in Rwanda, a number of agroforestry extension projects implemented by CARE International, and the Ministry of Energy program of agroforestry research and pilot extension in the Kenya Renewable Energy Development Project (KREDP). In geographic regions that cannot be served by research institutions in a cost-effective or reliable way, projects may be the only realistic option for agroforestry research (see Thiele et al. 1988).

A second model is the research-for-development field project. In this model, a multidisciplinary research team works to solve a defined set of field problems, on site, for a defined set of land users. An example of this approach is the CRSP Small Ruminant Project in western Kenya, which is exploring ways of introducing intensively managed dairy goats into the farming system in collaboration with the Ministry of Livestock Development. One component of the project is research on agroforestry alternatives for goat fodder production, and this activity is integrated with other components (goat breeding, goat management, and nutrition) in on-station, on-farm, and extension trials. Agroforestry research projects of this type are also found in integrated rural-development projects.

A third model is the establishment of formal linkages between research institutions and extension projects. In this model, the research activities are supervised and/or carried out principally by professionals in the research institution, but the extension project staff and farmers identify priority research problems and may participate in trial design and evaluation and on-site testing. An example of this approach is the collaboration between the

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KEFRI and CARE Agroforestry Extension Project in Kenya on species and technology testing for the project's main interventions (KEFRI and CARE 1986).

A fourth approach is the "action research" approach, in which strategic and applied research objectives are met in the process of carrying out a carefully documented development activity (Rocheleau 1987). A number of examples for agroforestry may be found. The Kenya Woodfuel Development Project (KWDP), a Beijer Institute project attached to Kenya's Ministry of Energy, sponsors research on agroforestry species selection, management, and extension methods, while carrying out an extension program. Other research projects of this type have been undertaken by ICRAF at its Kathama field site in Kenya (Rocheleau 1987; Raintree 1987) and, to some extent, by ILCA's alley-farming field projects in Nigeria (Atta-Krah and Francis 1987).

Collaborative Research Networks

A number of new research networks have been organized in recent years to increase resources for collaboration and information exchange between individuals and institutions doing agroforestry research. These have taken several forms, with varying levels of involvement by network organizers in research implementation, information exchange, and institutional development. The two principal models are the network as a conduit for research resources on specific agroforestry topics and the model of integrated agroforestry research planning, implementation, and institutionalization. The latter will be explained more fully below, as an example of institution-building for agroforestry research.

The research networks that deal with special topics include organizations such as the Nitrogen-Fixing Tree Association, the F/FRED network in Asia for research on fuelwood species, and the Alley-Farming Network (IITA/ILCA/ICRAF) in Africa. National collaborators receive financial support for research on network topics and commonly focus on multilocational trials through the network of collaborators. The networks provide a number of services, such as newsletters, workshops, training programs, etc., which enhance scientific interaction and improve the quality of research.

Since 1985, ICRAF has been helping to organize the Agroforestry Research Networks for Africa (AFRENAs), which represent a second network model designed explicitly for institutional development, as well as technology generation. The AFRENAs each include several countries and have been set up for the humid highlands of east Africa, the subhumid plateaux of southern Africa, the humid lowlands of west Africa, and the semi-arid lowlands of the Sahelian zone (Scott 1988; Torres 1987).

Coordinated research planning in the AFRENAs is institutionalized through a national agroforestry steering committee in each collaborating country, comprised of senior representatives of a wide range of research and development institutions with an interest in agroforestry. For each ecozone network, the role of policy-making, research, and budget review is undertaken by a regional steering committee, with representatives from each of the national steering committees. Day-to-day coordination of research is the responsibility of ICRAF zonal coordinators (Scott 1988).

The key implementing agencies in the AFRENA projects vary considerably from country to country and include examples of many of the above-mentioned models:

- an agroforestry research unit (Burundi);
- collaborating forestry and agriculture research institutions (Malawi, Tanzania, Kenya — with support from the energy ministry);
- a combined agriculture/forestry research institution (Cameroon, Rwanda);
- collaborating line ministries (forestry and agriculture in Zambia; forestry, agriculture, and livestock ministries plus the university in Uganda).

The network in southern Africa is coordinated by the Southern Africa Committee for Coordination of Agricultural Research (SACCAR), and the network now being formed in the sahelian zone of west Africa is coordinated by SAFGRAD.

The selection of research projects and objectives is based on a systematic process of land-use system diagnosis and agroforestry design. A multidisciplinary, multi-institutional task force is trained to implement a macro D&D of all major land-use systems for the steering committees to use as a basis for selecting priority land-use systems and agroforestry practices for research. This is followed by a detailed diagnosis and design (D&D) exercise in selected land-use systems to identify design priorities and constraints to development of selected agroforestry interventions and to prepare a research program (Scherr 1987b, 1987c).

Each project includes three parallel research activities: selection and improvement of MPTS germplasm for use in selected agroforestry practices, management trials to identify management options for specific agroforestry interventions (e.g., establishment, tree management, crop management, harvest), and design and testing of composite prototype systems for and with the identified client land users. Research in any of these lines may include

on-station experiments, on-farm experiments, or on-farm surveys of MPTS and farmer management in existing agroforestry systems, as determined by specific information needs for technology development. On-farm research may be organized directly by the research team or through collaboration with existing on-farm research programs or agroforestry extension projects.

All AFRENA training activities and D&D studies are undertaken with multidisciplinary groups. Research in each site-specific or zonal research project is undertaken by multidisciplinary teams of national and ICRAF scientists. ICRAF zonal outreach staff provide technical backstopping to project scientists in agronomy, forestry, soil science, and agroforestry; social scientists from headquarters will join them soon.

Relative Strengths of Different Institutional Models

Table 3 summarizes the strengths and weaknesses of the 15 different institutional models described above. This reflects what is characteristic of particular institutional arrangements, given their typical resources and structure. It is essential to recognize, however, that almost all identified constraints can be overcome through specific institutional interventions.

Institutional Coordination

In terms of effective coordination with other agroforestry researchers and with relevant policy and extension institutions related to agroforestry, the most successful single-institution model is likely to be the agroforestry extension institution, which includes research functions. One would also expect integrated land-use institutions to be strong in this area, but we have little experience with these. For the agroforestry research system as a whole, however, the integrated collaborative networks — as illustrated by the AFRENAs — seem to offer the best alternative for systematic, institutionalized, interinstitutional planning and consultation.

By contrast, disciplinary research or extension institutions will tend to find coordination difficult, while the independent research institutions (universities, independent researchers, and the private sector) are generally little concerned with institutional coordination. Extension projects are often geographically and institutionally isolated, even from other institutions operating in the same areas.

Development Focus

As would be expected, the institutions with the strongest institutional and researcher mandates for development-oriented research are the extension institutions, i.e., the researchers attached to national extension institutions

Table 3. Alternative Models for Organizing Agroforestry Research: Institutional Strengths and Weaknesses

Model	Coordi-nation	Devel. Focus	Multi-discipl.	On-Farm Focus	Inno-vation
Disciplinary Research Institute					
Disciplinary research institutions	–	?	–	–	–
Joint research projects	+	?	+	–	–
Agroforestry research institutions	+	?	++	–	++
Disciplinary Extension Institutions					
Disciplinary extension institutions	–	++	+	+	–
Agroforestry extension institutions	++	++	++	+	–
Integrated land-use institutions	++	++	++	+	+
Independent Research Institutions					
University research	–	+/–	+	–	+
Independent research support	–	?	–	–	+
Private-sector research	–	+	–	+	+
Project-Based Research					
Research based on extension projects	–	++	–	++	+
Research-for-development field projects	+	++	+	++	+
Research/extension project collaboration	+	+	+	++	++
Action research projects	+	++	+	++	++
Research Networks					
Special-topic research networks	+	?	–	?	+
Integrated collaborative networks	++	?	++	–	–

Note: This table represents the likely strengths and weaknesses of specific types of institutional arrangements in terms of the factors discussed in the text.
Ranking: ++ Strong + Intermediate – Weak ? Variable

or those attached to extension projects. It is difficult to draw generalizations about the other institutional models, as they are highly variable.

Multidisciplinary Coordination

Institutional models that could most easily provide multidisciplinary coordination include agroforestry institutions in research or extension and the integrated land-use institutions, which would have multidisciplinary staffing. Integrated research networks offer the potential for multidisciplinary, multi-institutional projects, although a major effort to develop multidisciplinary team mechanisms is often needed. This is also the case in joint projects between national research and/or extension institutions or projects.

Effective multidisciplinary teams may be the most difficult to establish in disciplinary research institutions, in smaller-scale extension projects, and among university researchers working either independently or in projects.

On-Farm Research Focus

Not surprisingly, the most effective on-farm research focus is found in those institutional models whose central activities are in the field, i.e., extension and action research. Such projects select research priorities based on problems identified with farmers during the extension process. They tend to focus on short- to medium-term research problems, and may be reluctant to carry out science-generating research with little immediate connection to extension. While some researchers raise questions about the longevity of extension projects from a research perspective, the evidence suggests that in many areas they are longer-lived than their government counterparts, which may suffer from major shifts in government resources over time (Thiele et al. 1988).

Typically, national research institutions and university-based or independent researchers will have the most difficulty establishing or accessing farmer networks for on-farm research. This may be overcome by linking up with existing farming-systems research programs or by linking directly with extension projects. The latter option, while promising, must be planned and managed carefully to ensure that there is a real congruence of research interests.

Environment for Research Innovation

One would expect that the environment for research innovation would be most open in agroforestry research institutions and in research-for-development field projects. In most cases, the mandate of these programs would promote innovation. By contrast, single-discipline institutions will not be provided with cross-disciplinary interaction, particularly where there is no regular contact with complex on-farm agroforestry. Those institutional models that require interinstitutional compromises for implementation may be forced into greater rigidity about methods and approaches because of the highly formalized planning process.

The Future Development of Agroforestry Research Institutions

Some tentative conclusions regarding the institutionalization of agroforestry research are suggested by the evaluation of agroforestry research systems undertaken to date.

The Future Profile of Agroforestry Research Institutions

The actual structure of research institutions appears to be less important to their capacity for carrying out good agroforestry research than the internal policies and arrangements regarding research coordination, development focus, multidisciplinarity, on-farm activities, and researcher innovation. There is probably far more room for maneuver within the framework of even fairly rigidly structured institutions than has sometimes been thought. Thus, the main aim of evaluating institutions in the agroforestry research system will generally be to identify weaknesses, strengths, and opportunities in existing institutions so that these can be effectively addressed in institutional planning, rather than to devise new institutions. The key to finding and exploiting opportunities within disciplinary research and extension institutions is the education of senior managers about the potential and needs of agroforestry research.

A wide range of modest modifications can be proposed in any type of institution to address weaknesses in the basic organizational structure or interinstitutional linkages. Research institutions without on-farm research facilities can develop collaborative programs with extension or on-farm research projects. Individuals with responsibility for research/extension linkages, or coordination with other research institutions, can be given more status and authority within an institution traditionally weak in coordinating its research planning and implementation. Secondment or direct hire of scientific staff from disciplines not traditionally found within the institutions, can be used to strengthen multidisciplinary teams.

The Role of Projects versus Institutions in Agroforestry Research

The main locus of agroforestry research in the past has been in either research or extension projects with operational independence that have had special status as pilot projects and innovators. As agroforestry becomes increasingly recognized as a mainstream scientific field, we can expect to see more agroforestry research move from these special projects to formal national research and development institutions. This will be especially true for the following: the long-term research trials that are required to obtain conclusive information about management regimes and sustainability of agroforestry systems, the research necessary to explain in detail how these systems work, and the more specialized types of research. The move to agroforestry research in formal institutions fits well into the general trend of research inter 's in integrated land-use management and sustainability.

But projects will continue to play an important role in agroforestry research, particularly if — as is to be hoped — more extension projects can improve their research commitment and capability. Their strengths are in the design,

testing, and adaptation of agroforestry technology for specific land users, and as collaborators with formal research institutions in on-farm research. They are likely to remain important innovators in the field. But perhaps their main role will be to keep agroforestry research demand-driven, i.e., focused on the research needs of farmers and extensionists, where pressures within formal institutions favor less practical research.

This potential needs to be exploited by the formal research sector. The agroforestry extension community should be represented on national steering committees and other decision-making bodies for research. Formal institutions and extension/development projects should seek active collaboration, to strengthen both the quality of research being undertaken in the projects and the ability of formal-sector researchers to identify and address key applied research problems.

Interdisciplinary Exchange of Methods and Findings

In the future, agroforestry researchers will need to develop greater "interdisciplinarity." Because of the current lack of solid interdisciplinary training and interaction, there is substantial reinvention of the wheel occurring in agroforestry, as disciplinary specialists are forced by the nature of agroforestry to move into fields for which they have not been trained. Agronomists, ecologists, foresters, horticulturalists, range managers, livestock-production specialists, socioeconomists, anthropologists, and rural extension specialists must be aware of one another's research methodologies and findings that are relevant to agroforestry, as well as their past experience with now-discarded methodologies. If provision for this sort of exchange of information and experience can be built into existing training and institutional arrangements, then research coordination, multidisciplinary work, on-farm research, and innovation could be substantially enhanced.

Research Support Institutions

Research institutions do not stand alone. Their policies and potential are strongly influenced by the general environment within which their scientists operate and have been trained. Managers of support institutions need to modify their perceptions and activities before one can expect research institutions to address agroforestry development needs fully. Of particular importance are donors, educational institutions, professional journals and organizations, and the agroforestry extension/development community.

Donor perception of the role and needs of research will have to change; much greater resources are needed for institutional and multidisciplinary staff development. At the same time, there is a striking imbalance between resources going to research and those going to extension in agroforestry.

This could be ameliorated by creative approaches to extension-research linkages and by donor recognition of the need for longer-term programs of scientific research to parallel the resources invested in technology-generating research.

Consistently high-quality research in national research institutions will require programs of professional education in the key disciplines that address the needs and perspectives of agroforestry. This is a major topic which cannot be discussed here, but it should suffice to insist that any program aimed at institutionalization of agroforestry research should logically be coupled with a parallel set of activities to institutionalize agroforestry in professional education (Zulberti 1987).

By the same token, agroforestry research is currently in an uncertain state as regards the professional output of researchers. The structure of professional organizations and publications is such that a premium is placed on disciplinary specialization. If institutions expect to attract and retain high-quality researchers in agroforestry, then more outlets must be developed and supported for rigorously peer-reviewed publication of applied, interdisciplinary agroforestry research.

Finally, the agroforestry extension/development community needs to shed its trepidation about undertaking research within its own projects and programs. The development community will for some time continue to bear the main responsibility for the development, improvement, and dissemination of agroforestry extension recommendations. This situation presents a clear mandate for a research component in most agroforestry development projects. This means the hiring and support of some staff with research capability — at least the ability to collaborate with formal-sector researchers to define research objectives, implement simple trials, and discuss research results. It also means some commitment on the part of these projects to share the results of technology-generating research and adopt methods of data collection that will facilitate this type of sharing (Raintree and Hoskins 1988; Scherr 1989). The CARE International/FAO Agroforestry Monitoring and Evaluation Methodology Project represents a step forward (Ngugi and Buck 1989), but greater efforts are needed.

Innovation in the Agroforestry Research Process

A final conclusion of this study is the need to maintain a perspective that sees the agroforestry research process itself as a subject for experimentation. There is a need to monitor and evaluate alternative institutional approaches to research planning and coordination, technology focus, multidisciplinary research, on-farm research, and opportunities for innovation. We also need to evaluate the cost-effectiveness of different types of research, undertaken

by different types of institutions, in generating and field-testing agroforestry technologies. Both ISNAR and ICRAF could play a valuable role in collaborating with national agroforestry institutions in this type of institutional research.

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USAID'S EXPERIMENT WITH THE PRIVATE SECTOR IN AGRICULTURAL RESEARCH IN LATIN AMERICA AND THE CARIBBEAN

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Abstract

The purpose of this study is to assess the methodologies used in planning the development of private-sector agricultural research institutions in Latin America and the Caribbean. Since 1984, the United States Agency for International Development (USAID) has supported new private-sector research institutions in Honduras, Ecuador, Jamaica, and the Dominican Republic and is now considering development of a new private-sector institution in El Salvador. Other similar institutions, particularly in Colombia and Chile, have existed for longer periods. This paper examines their development as part of a gradual institutional shift in agricultural research from direct governmental control towards greater autonomy. The shifts in institutional form reflect the desire to solve certain specific constraints to effective research programs: stability and levels of funding, professionalism, relevance of research, constituency support, and others. The potential ability of private-sector research institutions to actually overcome such constraints and to provide needed sustainable research, relative to other institutions, are analyzed.

Introduction

Since 1984, a new set of agricultural research institutions has been created in Latin America and the Caribbean. Initiated and supported by the United States Agency for International Development (USAID), they are self-defined as "private-sector" research foundations. In the last four years, five foundations have been established in Honduras, Jamaica, the Dominican Republic, Peru, and Ecuador, and two more are being considered in El Salvador, and Guatemala. These new organizations challenge traditional institutional relationships between public- and private-sector research in many coun-

tries, reallocate national research priorities and resources, and may have important long-term implications for the modernization of agriculture in Latin America.

These foundations are being created in the smaller countries of Latin America and the Caribbean where USAID still maintains assistance programs (see Figure 1). USAID's total portfolio in agricultural research is approximately $120 million; agricultural research support has been consistently supported in the region for over two decades. USAID continues to support two regional agricultural research centers, Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), which provides assistance to Central America, and the Caribbean Agricultural Research and Development Institute (CARDI), which has the lead research role in the Caribbean. USAID also funnels resources to national research programs on a small scale through a variety of projects. However, with the exception of Peru (where the mission directly supports both a foundation and the public research system), there have been no new bilateral USAID programs for direct strengthening of public-sector research in over five years. Hence, the foundations represent a modification of the agency's traditional support for research. They raise important issues about the nature of institutional reform in agricultural research and the nature of agricultural technology development in Latin America.

This paper describes the growth of the foundation projects and then briefly describes the foundations, which differ considerably in purpose, scope, and activities. Then it analyzes the institutional and economic justification that led to the decision to create them. The justifications, as presented in USAID project documents, provide a means of analyzing which aspects of the agricultural technology sector USAID considers important — and unimportant — in deciding whether to assist agricultural research and, if so, how to provide such assistance. Finally, it suggests other issues that should also be considered in establishing a new research institution.

The Historical Context of USAID-Supported Research Foundations

Private-Sector Research Institutions

From a historical perspective, nongovernmental foundations can be viewed as one more step in the institutional evolution of agricultural research in Latin America, building on changes in both public- and private-sector capacities. In the private sector, large producers of traditional export crops such as sugarcane, coffee, cocoa, and bananas have maintained and paid for research programs for their commodities, often through government institutes. Examples include the Sugar Institute in Colombia and the Instituto

Figure 1. USAID assistance programs in Latin America and the Caribbean

del Café in Costa Rica. This model of research has not generally proved appropriate, however, for supporting research activities across a broad spectrum of commodities, in situations where agricultural goods are primarily for domestic consumption, nor where the structure of production of a commodity is based on small landholdings. This is because this organization of research does not facilitate the private appropriation of the returns to investment in research. The private sector will not invest where the specific investors cannot capture the gains of the research. As a result, private-sector

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research investment and institutional development is low in Latin America at present.

In the 1970s, two private-sector agricultural research foundations were created. In Chile, ITT Corporation and the Chilean government signed an agreement in 1976, creating the Fundación Chile, with a large endowment from ITT and the Chilean government. It was established to act as a technology "bridge," transferring international technologies to Chile with the objective of broadly improving utilization of the nation's natural resources and productive capacity. It has become a large, stable applied-research and technical-assistance organization, working not only in agriculture but also in communications, computers, and other fields. Approximately 40% of its budget comes from the endowment; the other 60% from contracts with governments and agrobusiness groups. Shell Corporation in Venezuela created Fundación de Servicio para el Agricultor (FUSAGRI) in 1972 on a more modest scale. It provides both applied-research and extension services to farmers in four Venezuelan states; about 15% of its funding is derived from its endowment, while the rest comes from contracts.

Public-Sector Research Institutions

In general, however, national governments have assumed the dominant role in financing and planning agricultural research in Latin America, considering it an important state function. The economic argument for doing so is that public investment should fill the void left by a reluctant private sector inasmuch as public investment provides social returns not easily appropriated by private research efforts. Historically, government-supported agricultural research seems to have passed through similar stages of institution-building. These can be briefly characterized as

1. The development of separate, relatively autonomous experiment stations, primarily focused on specific problems in export crops such as cotton and sugarcane. Experiment stations began to proliferate in the second and third decades of the twentieth century.

2. The consolidation of research stations into a single research unit within the Ministry of Agriculture, beginning in the late 1950s and early 1960s.

3. The gradual evolution of the research unit into "semiautonomous" status, usually within the Ministry of Agriculture, with a centralized bureaucracy but some degree of decentralized research activities, mostly occurring in the early 1970s.

4. In some cases, a final step in which agricultural research is housed in a completely autonomous government institution, often not part of the

Ministry of Agriculture, and specifically not subject to civil-service regulations. An example of this last case is EMBRAPA, established in 1974 in Brazil.

This evolution is not inevitable, and certainly not easy. Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Ecuador, for example, was close to the fourth step in terms of autonomy in the past, but at present is probably closer to step three or two. The Ecuadorian government is currently examining this issue again, and it is clear that there are important political, as well as technical, forces that need to be marshalled to make such an institutional change. The frustrating experience in the Dominican Republic over the past six years have created IDIA as an autonomous research institution — not yet successfully accomplished — and offers other evidence of the difficulty in moving towards greater autonomy. These difficulties may help explain why the pace of institutional change has slowed since the mid-1970s.

In addition to supporting institutional change in research in the 1960s and 1970s, Latin American governments also increased their financial commitment to agricultural research. Research expenditures rose steadily in the 1960s and 1970s; however, this was against a very low base — even after two decades of increasing support, budgets for agricultural research as a percentage of agricultural GDP were still well below the "recommended" FAO level of one to two percent in 1980/81. This was particularly the case with the smaller countries.

Just as there appeared to be a loss of momentum on the institutional side in the 1980s, budget support for agricultural research also began to slip badly under the debt-induced pressure of structural adjustment characteristic in most countries of the region. For example, the agricultural research budget in Ecuador has decreased approximately 15% a year for the past eight years and is now a small fraction of what it was a decade ago. Although the decrease has not been as dramatic, support for ICTA in Guatemala has also declined in real terms in the 1980s. In the Dominican Republic, financial support has fluctuated greatly, but the trend is clearly downwards at a precipitous rate. For 1988, it is estimated at only 0.16% of agricultural GDP — about one-tenth of FAO-recommended levels.

In summary, the national systems of agricultural research in Latin America against which USAID support for foundations has developed include (1) few private efforts to develop agricultural research institutions; (2) gradual evolution of governmental research towards greater centralization of priority setting and planning, and greater autonomy from governmental regulations, which seemed to slow down in the 1980s; (3) increasing financial

support for agricultural research in the 1960s and 1970s, which has not been maintained in the 1980s.

USAID Support for Agricultural Research in Latin America

Table 1 shows current and planned USAID projects involving agricultural research in Latin America. USAID assistance has supported, and at times led, institutional changes in agricultural research. In many countries, the agency has offered sustained support over long periods of time. In Colombia, for example, USAID funded activities for 18 years, from 1962 to 1980. In El Salvador, there has been continuous support for agricultural research from 1963 to the present — 25 years. USAID in Honduras had various projects supporting public-sector research for 20 years, from 1964 to 1984. These are only a few of many examples.

In addition to providing reasonable constancy of support, USAID projects have favored and sometimes taken the lead in moving government research activities into new institutions. In Guatemala, USAID assisted in the design of ICTA; in El Salvador, it helped establish CENTA; and in Brazil, it strongly supported the move of research activities from within the Ministry of Agriculture into a new autonomous parastatal, EMBRAPA.

While USAID has often provided reasonably long-term and coherent support and has addressed itself to institutional strengthening, this support has been accomplished through a series of short-term projects rather than through long-term program support. A historical analysis of USAID projects in this field shows that most of the agency's support has been towards technical rather than institutional objectives, concentrating on solving specific research difficulties or supporting a particular commodity. This form of support has undoubtedly weakened its ability to overcome some endemic institutional deficiencies, such as budget instability. The lack of core support to institutions in less-developed countries from foreign donors has often been cited as one reason for the institutional weaknesses that exist in these countries. On the other hand, from the donors' perspective, project support has allowed greater precision of research objectives and control over them.

The Creation of the Research Foundations

The Environment for Institutional Change

USAID's decision to move from direct support of public research to creating new foundations did not develop consciously from the idea that the foundations presented another step in institutional evolution. Nor have project design documents analyzed the two best-known private-sector foundations already in existence, Fundación Chile and FUSAGRI. In fact, the move to

Table 1. Current and Planned AID Projects in Research and Research Training

Project Number	Description	Initial Year	Final Year	Total Cost	Research Cost	Research Cost
				US$ 000	*US$ 000*	%
CARIBBEAN						
BELIZE						
505-000B	Commercialization of Alt. Crops	1985	1988	6800	2500	37
DOMINICAN REPUBLIC						
517-0159	On-Farm Water Management	1983	1989	12000	3000	25
517-0214	Commercial Farming Systems	1988	1992	14000	4620	33
HAITI						
521-0092	Ag. Development Support II	1978	1989	3808	768	20
521-0122	Agroforestry Outreach	1981	2990	27000	2700	10
521-0191	Targeted Watershed Management	1986	1991	15000	1800	12
JAMAICA						
532-0128	Ag. Research Project RDO/C	1986	1993	7600	7600	100
538-0099	Farming Systems R&D (CARDI)	1983	1988	7550	7550	100
CENTRAL AMERICA						
COSTA RICA						
515-0237	Nontraditional Ag. Exp. Tech. Support	1987	1991	3500	420	12
Local Cur.	Nontraditional Ag. Exp. Program	1986	1988	1800	360	20
Local Cur.	Coffee Rehabilitation Program	1985	1992	20000	600	3
EL SALVADOR						
	Agrarian Reform Sector Support	1983	1987	50750	3553	7
Local Cur.	Integrated Pest Mgt. (ROCAP)	1986	1987	260	260	100
Local Cur.	Animal & Plant Health Res. (USDA)	1986	1987	1000	1000	100
Local Cur.	CENTA Institutional Support	1987		200	200	100
Local Cur.	Fuelwood & Alt. Energy Sources	1987		100	100	100
Local Cur.	Fisheries Research	1986	1987	1580	1580	100
GUATEMALA						
Local Cur.	Multiple Projects	1987	1990	12200	1200	10
HONDURAS						
522-0249	Ag. Research Foundation (FHIA)	1984	1994	20000	20000	100
Local Cur.	Ag. Research Foundation (FHIA)	1987		1500	1500	100

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Table 1. (Continued)

Project Number	Description	Initial Year	Final Year	Total Cost	Research Cost	Research Cost
				US$ 000	US$ 000	%
522-0157	Rural Technology Project	1979	1988	9000	970	11
Local Cur.	Research on Comayagua Farm	1987		2250		100
	Insorall CRSP (AID/S&T)	1981	340	340	100	
Local Cur.	Insorall CRSP (AID/S&T)	1987		50	50	100
Local Cur.	Min. of Nat'l. Resources: Research	1987		1836	1836	100
522-0168	Natural Resources Management	1980	1989	16100	25	0
PANAMA						
525-0222	Ag. Cooperative Marketing	1984	1989	8200	750	9
525-0227	Ag. Technology Transfer	1984	1989	7500	400	5
ROCAP						
596-0127	Ag. Research Networks	1987	1994	2500	2500	100
596-0017	Tree Crop Production	1985	1989	9000	2250	25
596-0110	Integrated Pest Management	1984	1989	6750	473	7
596-0090	Coffee Rust and Pest Control	1981	1987	3500	2975	85
596-0125	Reg. Higher Education	1986	1994	2500	2500	100
SOUTH AMERICA						30
PERU						
527-0282	Ag. Technology Transfer	1957	1992	25000	20500	82
527-0192	Ag. Research and Extension	1980	1987	19650	7100	36
527-0240	Central Selva Research	1982	1989	22000	1600	7
527-0244	Upper Haullage Area Development	1981	1988	23400	2900	12
BOLIVIA						
511-0543	Chape?? Regional Development	1988	1991	12500	1250	10
Local Cur.	Support for Agric. Research	1987		950	950	100
ECUADOR						
518-0066	Ag. Res. Extension & Education	1988	1993	7000	7000	100
Local Cur.	Ag. Res. Extension & Education	1987		19	19	100
518-0032	Rural Technology Transfer System	1980	1988	7900	618	8
518-0023	Forestry Sector Development	1982	1990	8100	1900	23
	Total			402693	120216	30

Note: Local currency numbers represent the current level of support, which may be continued as local currency funds permit.

create research foundations was not precipitated by an overall strategic decision of any kind. Rather, it was arguably the result of two internal USAID characteristics, plus an opportunity presented in 1984 in Honduras, that lent initial appeal and feasibility to this idea.

The first USAID institutional factor is undoubtedly the agency's emphasis on support for "private-sector alternatives," and its increasing reluctance to continue the support of government organizations. The "private sector" as one of the "pillars of development" was taken particularly seriously within the Bureau for Latin America and the Caribbean, both in Washington and in missions. This had immediate consequences for agricultural research support. In the Dominican Republic, for example, USAID had been working with the government and ISNAR to develop a project pushing the government research program into a separate, more autonomous (but nonetheless still publicly financed and run) institute. With the arrival of a new mission director in 1985, USAID abandoned this approach, explicitly looked for more "private-sector" alternatives, and within two years had taken the lead in creating a new private-sector foundation. In another case, a proposal for establishing a centralized training program for agricultural research managers was explicitly rejected because most of the trainees would be from the public sector.

The second USAID factor could loosely be termed "institutional fatigue." To a large extent, the very continuity of support that strengthened agricultural research became a liability. USAID missions are simply tired of continuing to support the same organizations year after year. There is a sense that the agency has been funding government research for a decade or more, and that it is time to move funds elsewhere. This is not an economic argument at heart — agricultural officers are generally aware of the high social returns to investment in agricultural technology. They understand the slow process of institutional strengthening and are knowledgeable about the decades it took to develop a sustainable research capability in the United States. Rather, it is rooted in USAID's own institutional biases — the desire for innovation, the desire to "make one's mark" in development by creating something new, the assumption that action of any kind (such as creating a new organization) is evidence of progress. Institutional studies of USAID have pointed out this tendency across the spectrum of development activities. It may also be that USAID project managers see the worst of a research institution — weak leadership, inept management, continuous financial crises — and may be less likely to see individual farmers changing crop varieties over a period of time and the society realizing a gain in agricultural productivity that is directly attributable to the research investment. The perception of failure may at times be worse than the reality. The total effect of these factors is to discourage continued support of public-sector research institutions.

These two "background variables" — USAID's private-sector thrust and its bias towards creation of new institutions — are important for understanding the appeal of an entirely new, private-sector-led approach to agricultural research in Latin America. However, if a unique opportunity had not been present in Honduras in 1984, it might well have been that the agency would simply have cut out most of its support for government research and moved out of research support. Honduras seemed to offer a practical new way.

USAID-Funded Research Foundations in Latin America

Table 2 shows the agricultural research foundations supported by USAID in Latin America.

Table 2. Agricultural Research Foundations Supported by USAID in Latin America

Country	Name	Project Dates	Project Length (years)	Funding (US$ millions)
Honduras	FHIA Fundación Hondureña de Investigación Agrícola	1984/94	10	20 grant
Jamaica	RAC/JADF Research Advisory Council of the Jamaican Development Foundation	1986/93	7	7.6 grant
Peru	FUNDEAGRO Fundación de Desarrollo Agropecuario	1987/93	6	7.3 grant
Dominican Republic	ADF Agricultural Development Foundation	1988/93	4	4.6 grant 12 local currency
Ecuador	FUNDAGRO Foundación de Desarrollo Agripecuario	1988/93	5	7 grant 2 local currency
El Salvador*	FUSADES Fundación Salvadoreña para el Desarollo Económico y Social	1989/99	10	20 grant
Guatemala*	FIAA Fundación de Investigación Agrícola Aplicada	1989/-	—	—

*Proposed

The Fundación Hondureña de Investigación Agrícola (FHIA)

Honduran governmental research efforts began in the early 1950s with the Inter-american Technical Service for Agricultural Cooperation (STICA), which was responsible for both research and extension. STICA and its institutional descendants, DESARRUAL and PINA, were recipients of USAID assistance, as well as assistance from other donors. By 1983, a series of studies and evaluations from numerous sources (including the Presidential Agricultural Task Force and the USAID Research Priorities Field Team) had concluded that the research system still had significant shortcomings and was in need of serious reform. It had no control over its budget, and there was a serious shortage of trained manpower. It was largely restricted to station-based varietal testing and agronomic trials, the research stations were weak, and there were limited linkages to other research institutions.

Also in 1983, United Brands decided to shut down its long-term research station at La Lima, Honduras, one of the foremost banana research stations in the world. The company felt it could no longer afford to carry out the research, regardless of its value, because it was unable to profit as a company. The Honduran government, USAID, and United Brands together came to an agreement to create a private-sector foundation. The Fundación Hondureña de Investigación Agrícola (FHIA) was established in 1984, supported by a $20 million grant over 10 years from USAID. Dr. Fernando Fernandes, a respected figure in international agriculture, was appointed its first director. The board of directors included the minister of agriculture, the USAID mission director, and representatives from private agricultural interests, and it immediately set out an ambitious plan of action.

The goal of FHIA was to contribute to increased income for farmers and to generate employment in Honduras by increasing agricultural productivity, particularly for small and medium-sized farmers. It was to emphasize nontraditional export crops, but it was also to have a program to increase productivity of traditional exports and to support government research on basic grains as well. It was to develop not only a strong research program, but an innovative dissemination program, partly with the government extension service and partly through nontraditional media programs. With its 38 professional and 50 support staff, it developed six commodity programs. The financial viability of FHIA was based on projections that it would earn money through research agreements with the government (particularly in basic grain research) and through contracts with private-sector groups, as well as on future support from other donors. Altogether, it was a highly ambitious undertaking: to create a new, self-supporting research institute capable of carrying out research on a wide range of commodities, with a national development perspective, a small, highly qualified staff, and a 10-year start-up grant.

The creation of FHIA generated great excitement within USAID's Bureau for Latin America and the Caribbean. During Washington reviews, it was widely touted as an "alternative" to working with a badly weakened public sector. It was also "innovative" (an accolade of high praise). While it was to undertake research on basic grains and other products on which most small-scale producers based their livelihoods, its major thrust was to be in export crops. This fitted to a tee the macroeconomic concentration in USAID on supporting programs to increase foreign exchange earnings.

Catalyzed by the enthusiastic reaction to FHIA in Washington and impressed with the potential of this approach in other Latin American countries, USAID missions throughout Latin America quickly began examining the possibilities of "private-sector" foundations in their own countries. In some missions, research foundations seemed to offer a solution to a serious rift between technical agricultural officers (who were convinced that long-term support of agricultural research was of paramount importance) and mission directors (who wanted to show "short-term" results, were not convinced of the need for research in any case, and were unenthusiastic about — and in some cases hostile to — continuing support of public-sector research).

Jamaica: The Research Advisory Council

Within two years, a second research foundation was created in Jamaica. In this case, a foundation had already been set up, funded through local currency generated from USAID food programs, to provide agricultural credit. Rather than setting up a different foundation, USAID grafted a somewhat independent new group onto it, the Research Advisory Council (RAC), in 1986. As in Honduras, USAID saw that the composition of the board of directors was of paramount importance in building a constituency for the new institution and establishing its credibility. One representative from the ministry of agriculture is on the board, as are representatives from agricultural education, credit, and other private-sector groups. Also, as in Honduras, the RAC solution arose in large measure out of frustration with the pace and capabilities of public-sector research.

The project paper noted that government research had received considerable assistance from international donors, but the funds had failed to stimulate any sustained institutional improvement. It viewed the "fragmentation" of the research system, with its lack of coordination among public-, quasi-public-, and private-sector groups, as the most serious problem, in addition to the lack of clearly defined policies and priorities, weak linkages between research, extension, and farmers, and the low government research budgets.

Unlike the Honduran case, however, the RAC in Jamaica did not establish its own cadre of researchers and its own facilities. Instead, it proposed to identify national research priorities and to fund research directed at these priorities through grants and contracts to individual researchers. The focus was at the farm level, where research needs were to be identified and applied research largely carried out. This was to help build a constituency for research support that would in the long run help the government's own research programs. In addition, the RAC was charged with developing criteria for and funding better scientific interchange between national and international sources of technology, as well as developing criteria for funding short-term training in research.

Establishing final research priorities was left up to the RAC, but the USAID project paper suggested five commodity groups. Unlike FHIA, with its emphasis on exports, the RAC gave equal weight to domestically consumed and exported commodities. This was based on an economic analysis of the potential benefits of a range of commodities.

At this time, the question of sustainability of a private-sector foundation was beginning to emerge. Once USAID project funding ceased, how was the foundation to continue operating? The Honduran mission had attempted in 1984 to set up an endowment with its grant funds, but USAID regulations prohibited it. As a result, FHIA's financial analysis was based on creative projections of future income streams from the Honduran government and other donors, and payments from agricultural groups for research services. The RAC in Jamaica was faced with the same question and dodged it, merely recommending exploration of the possibility of an endowment financed through local currency from USAID food programs. At the outset, the RAC was financed 100% by USAID, through a grant of $7.6 million over seven years.

The RAC was established as a more modest organization than FHIA. Although completely independent in decision making from the JADF, it was nonetheless under its administrative control to some degree. Its institutional ambitions were clearly smaller, since it had no research staff of its own. The project hoped the RAC would strengthen research and extension efforts in Jamaica in general, through training, funding of specific research projects, and development of an alternative organizational model of research and extension that could be picked up by the government. Cooperation would clearly be necessary in the future if the government were asked to cede its local currency funds as an endowment to the RAC. However, other than having government representation on the board of directors, the project did not foresee any institutional relationship with the government, nor did it solicit government assistance in creating the RAC.

Peru: Fundación de Desarrollo Agropecuario (FUNDEAGRO)

In contrast to Honduras and Jamaica, the government research institution, INIAP, took the leadership in helping create a foundation in Peru, after USAID technicians broached the subject. The executive director of INIAP viewed a foundation as a convenient means of bypassing some of the onerous salary regulations debilitating the agency. He asked the National Farmers' Organization to establish it legally, as FUNSIPA, using an USAID grant. At the time of organization in 1986, the board of directors included the National Agricultural University, the National Farmers' Organization, INIAP, and the International Potato Center (CIP).

Unfortunately, the minister of agriculture's collaboration was not sought, and he opposed the foundation. Partially as a result, the INIAP director was replaced, and the new director began a legal investigation of the foundation. Once its legality was confirmed, the foundation limped along, managing small contracts from international donors, including USAID. The government made little use of it.

What turned the foundation into a potentially useful organization was a new USAID project ("Agricultural Technology Transformation"), a complex project with many components to be implemented by a variety of groups. After an analysis of alternatives, USAID chose FUNSIPA to manage major sections of the project and gained the government's assent to support it. The process of project planning convinced the INIAP director that the foundation could benefit public-sector research, and he became one of its strong supporters. There were serious setbacks in gaining final approval from the ministry of agriculture for the project, with the minister worried about the implications of a "private-sector approach," but an agreement was finally signed. One consequence of these negotiations was to broaden the base of FUNSIPA and its mandate. Its name was changed to FUNDEAGRO, and the board increased in size to include not only the four original members but the ministry of agriculture, ADEX (an association of agricultural exporters), and the dean of the Association of Agricultural Professionals. The head of INIPA, who had resigned from his position over struggles with the ministry to develop the foundation, was made executive director. FUNDEAGRO was given the responsibility of managing major parts of the new $25 million USAID project, as well as a $7.3 million grant in the seven-year project.

The USAID project attacked the whole range of agricultural technology problems in research, extension, and education. The analysis behind the project included background studies of the return on public-sector research and extension (which ranged from 15% to 40% for the major crops) and institutional analyses of INIPA (which was later divested of its extension responsibilities and renamed INIAA) and extension groups. It had specific

responsibilities to develop a competitive research grant program, improve pedagogical and training materials, and establish a competitive scholarship program. What was to be most important, however, was its national leadership role in agricultural technology. This meant addressing problems of human resource development within the universities and improving research and technology-transfer linkages, as well as linkages with international sources of technology and technology users. To be successful in this role, FUNDEAGRO clearly needed the support of both government and nongovernment groups.

It was assumed at the outset that there were many scientists who had left the public sector and who would be available for work with FUNDEAGRO. In practice, however, most researchers contracted have come directly from INIAA, either retiring or leaving, causing a "brain drain." FUNDEAGRO salaries are four to five times higher than INIAA's. On the other hand, INIAA employees have taken important positions in FUNDEAGRO and are committed to improving public-sector research. It is premature to judge how these factors will balance out.

Hence this foundation has a public purpose: it works with both public- and private-sector forces, it is funded from public sources (including USAID), and it has a seven-member board with three members from public institutions and four from private groups. It thus represents an amalgam of those groups most interested in agriculture in Peru.

However, its long-term financial viability has yet to be shown. At present, it is funded through a seven-year project. Unless the foundation is successful in capturing new sources of funding, it will not survive past project funding.

The Dominican Republic: The Agricultural Development Foundation (ADF)

The year following the establishment of FUNDEAGRO, the ADF in the Dominican Republic was set up under USAID impetus. Like every foundation except FHIA, it planned to use contracts and grants to researchers to accomplish its objectives rather than create its own scientific staff and physical facilities. The researchers were to come from government, universities, and agribusiness. Also, like the other foundations, it was concerned about linking research and technology-transfer activities.

Historically, it is interesting as the most explicit case of USAID abandoning a public research effort for a private research alternative during project planning. The earlier, public-sector, effort was squarely focused on public "institution building," attempting to reform and rationalize the agricultural technology system. A number of background studies commissioned by USAID and ISNAR have pointed out low salaries and budgets, a lack of research and

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extension integration, politicization, and other problems of the government research effort. USAID concluded that the present agricultural research system in the Dominican Republic had "demonstrated an inability to carry out and disseminate relevant research in most of the basic food crops" (with the exception of rice).

USAID also argued that the government's efforts to move research from the domain of the secretary of agriculture into an autonomous institution, given the restrictions that accompanied the change, would lead to no fundamental shift in capacity or flexibility, but would simply amount to a change in names. Essentially, creating an entirely new institution, outside the government, was a better investment than trying to reform the current one. It therefore supported the idea of establishing a new, private-sector foundation to provide technological assistance to farmers.

The new foundation had a number of unique characteristics. First, it was limited, at least initially, to supporting research on nontraditional export crops. Nontraditional exports in agriculture had grown rapidly, from about $20 million in 1979 to about $53.5 million in 1986, and the economic analysis calculated that a research investment in this area would yield returns of 35% by year five. It had no broad objectives of improving the agricultural technology system.

Second, the term "private sector" acquired a much more specific meaning than it had in the other foundations. In the Dominican Republic, USAID encouraged members of the National Businessmen's Council to create the foundation and become its founding members. They were then responsible for establishing its bylaws, organizing it, *and* for helping finance it. USAID, in fact, made the release of its own funding contingent on counterpart funds received from the private sector, and contributions actually came in at a much faster pace than expected. This was the first, and so far the only, foundation that has actually required the private sector to come up with financing, not for specific services, but as part of the core budget of the organization.

Finally, it made the most detailed financial plans to try to ensure financial sustainability after USAID project funding ceased. The most important mechanism was the creation of an endowment using local currency generated through USAID sugar-quota funds (about $12 million). This required the collaboration of the government (whose money it was) and meant, of course, that the government of the Dominican Republic was helping fund the foundation. Under considerable persuasion from USAID, this collaboration was forthcoming, though not enthusiastically; the government's initial position was one of skepticism. In other cases, however, some key govern-

ment leaders strongly favored this approach. Once the endowment was created, the government had no control over how the funds would be spent.

Matching grants from the private sector were a second source of income. The private sector was committed to raising about $750,000, half of which has already been collected. Finally, USAID also granted $4.6 million to the foundation over a seven-year period. It was also expected that the foundation would earn some money directly for services, but the analysis of financial viability did not depend on this less-certain source of income. On the basis of this income, and the interest from it, the foundation should have a yearly budget of approximately $1 million.

Ecuador: Fundación de Desarrollo Agropecuario (FUNDAGRO)

Initial planning for a new private-sector agricultural research foundation began in the USAID mission in Ecuador in 1986. It took over two years before a project was finally approved in May 1988. Some of this delay can be explained by changes in the USAID mission during that period, but it is hard to imagine a more contentious, divisive process than that which took place within and outside of USAID during the creation of first one foundation (FEDIA) and then a second (FUNDAGRO).

In this case, members of a US Presidential Task Force visiting Ecuador suggested that the USAID mission consider funding a research foundation as a means of overcoming weaknesses in public-sector research and extension organizations and to involve private-sector interests to a greater degree. This idea was seized on by the minister of agriculture, an outspoken critic of government bureaucracy, who saw the foundation as a way of bypassing government regulations and weakening public-sector unions. He successfully urged the president to establish FEDIA by decree as a nongovernmental, nonprofit research foundation. USAID handled start-up costs through a grant and selected an executive director. The minister's intention was to move much of INIAP into FEDIA and "privatize" the national research program. He also appointed the initial FEDIA board of directors. Not surprisingly, his actions politicized the idea of a research foundation, and even after he left office, strong opposition to FEDIA remained. To many, in and out of government, FEDIA represented a particular political faction.

Once it became clear that FEDIA would not absorb INIAP, USAID began stressing the role of the foundation as a "catalyst" to improve the entire agricultural technology sector. There also began a gradual, hesitant effort to widen the support base of FEDIA and demonstrate that it was not the puppet of one individual. This was done primarily by increasing the board representation and reestablishing the foundation under normal laws with a new name, FUNDAGRO.

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Long-term political viability and narrow support were two criticisms of the foundation project when it was presented for review in Washington. Another, equally fundamental, was institutional: "What is the basis of assuming that the proposed institution will be more capable of addressing the constraints to research, extension, and education . . . than a project which works directly with the existing institutions?" (from the Washington "issue paper"). In fact, FUNDAGRO seemed ambivalent on the subject of what government institutions were actually capable of doing. FUNDAGRO's own analysis of government research, extension, and education in agriculture was scathing and unrelenting (USAID Project Paper): low budgets, politicization, lack of leadership, priorities, and linkages to clients and to extension services; professional decline due to isolation, bad incentives, and archaic hiring practices. The litany of defects of public-sector research was unrelieved by a single bright spot. Extension and education services fared no better. The critique, however, had no serious economic analysis. On the other hand, as a "catalyst," FUNDAGRO proposed to work with the very institutions and researchers it found so hopeless. In fact, it has quite successfully established formal research agreements with INIAP in several commodities.

After the months of uncertainty, FUNDAGRO began to sound similar to FUNDEAGRO in Peru. Its purpose, while unwieldy, reflects a general commitment to a national perspective:

> . . . to develop the capacity . . . to serve as a catalyst for the establishment of an improved and integrated agricultural research, extension, and education system in selected commodities, which fortifies and expands upon the efforts of existing public and private research, extension, and education efforts, to deliver a steady flow of productivity-increasing, cost-reducing technologies to a wide spectrum of farmer-client groups, with special interest in small and medium-sized producers.

Like its Peruvian counterpart, it looks at the entire agricultural technology sector. In this case, it will focus on creating "research/extension units" in specific commodities as an attempt to improve linkages between research and extension organizations. Both institutions will rely on existing institutions to supply the researchers, extension, and other technicians necessary to carry out their activities.

Unlike the case in Peru, however, FUNDAGRO has a small endowment of approximately $3.3 million from local currency derived from USAID programs, as well as a five-year grant from USAID of $7 million. It also plans to generate about $120,000 per year from private-sector sources. These amounts are not enough to ensure its long-term stability, or even viability, however, and it, like the other foundations, actively seeks contracts with other international and national groups.

Future Foundations: El Salvador and Guatemala

USAID missions in El Salvador and Guatemala are now developing projects to support similar private agricultural research organizations. They are currently examining many of the issues raised here, such as financial viability and long-term relationships to other research institutions, and it is not yet clear what the final products will look like. It appears likely that the El Salvador mission will add research activities to FUSADES, a foundation it created in 1984 to promote exports. In the case of Guatemala, there are intriguing institutional questions because a private-sector foundation was already established last year with the support of ICRA. In both countries, the national research institutions were once highly respected but appear to be in decline.

If these two projects go forward, by the end of fiscal 1989, USAID may be funding seven, new, private-sector agricultural research foundations.

Factors Important in Developing Research Foundations

The case studies demonstrate that the foundations were not created through an overall strategic plan, nor were they the result of careful analysis of problems and successes of earlier foundations. After FHIA in Honduras, they all developed nearly simultaneously. With the exception of FHIA, all rely on existing institutions for the skilled researchers and extensionists they need. They have all made some effort to establish research priorities, although in some cases these are as broad as the priorities of the government research program. They share a common administrative structure. Each is run by an executive director and a board of directors dominated by private-sector representatives. They vary considerably in other institutional details, however, such as membership and advisory councils. They also vary in terms of commodity focus, client groups, and financial sustainability.

The foundation idea spread quickly, and the forms and purposes of the foundations created varied greatly. Nonetheless, it is possible to make a few generalizations about the factors that USAID seemed to consider most important in justifying the new research foundations. The following section is based on an examination of the USAID project documentation and background papers related to developing the agricultural research foundations. The factors seem to divide naturally into two groups: critiques of the agricultural technology system before the foundation and perceived opportunities offered by a private-sector foundation alternative.

USAID Critiques of the Agricultural Technology System

In every case, the USAID analyses of the national agricultural research systems were sharply critical. The emphasis was on the weaknesses in public-sector research and extension, often to such an extent that it seemed hard to believe that the new foundation intended to rely mainly on professionals in the public sector to carry out its own research and extension activities. In no case was a foundation viewed as a mechanism to assist an even moderately functioning system, with the possible exception of Peru.

Second, the analyses concentrate on administrative problems in the current organizations, rather than on financial problems or economic gains and losses from the research investment. They focused on the inability of the government research organizations to impose rigorous research priorities, to offer salaries and incentives that would retain talented professionals, and to develop flexible and competent management and financial systems.

Third, the analyses focus on the disjunction between research and technology-transfer activities. In each of these systems, research and technology-transfer are carried out by separate organizations. USAID has tried for many years to overcome professional and organizational differences to ensure that research findings make their way into extension efforts and that extensionists communicate their understanding of farmer needs to researchers. Sometimes this has been accomplished by focusing on an individual commodity and bringing together technicians from different organizations to work on it. At other times, special groups such as the "enlaces tecnologicas" in Honduras have been established. But USAID has not yet succeeded in developing a sustainable method for coordinating research and extension; the foundations are the most recent organizational mechanism favored to improve it.

Fourth, the analyses point out that the national institutions do not fully exploit international sources of agricultural technology. Thus, the isolation of researchers, the duplication of research being done elsewhere, and the failure to come up with quicker solutions based on adopted technologies are salient points of criticism. One activity that every foundation is to undertake is to improve linkages between international and national sources of technology. This concern is a fairly recent one. In part, it can be attributed to the successes of the international and agricultural research centers, particularly CIP, CIMMYT, and CIAT in Latin America, which have technologies to extend. In part, it is attributable to USAID's interest in developing research in new commodities, particularly nontraditional export crops, in which there is little national research experience. It has also become a more important element in research development because USAID assistance in the region is targeted to the smaller countries. The smaller human resource base and

limited resources that can be allocated to research make it imperative in these countries to look elsewhere for technological improvements.

Finally, the research systems are criticized because they are not responsive to the research needs in the sector. There are few formal linkages between farmer groups or agroindustry and agricultural technology-development institutions. Priorities are established and research activities undertaken without the collaboration or involvement of the potential users of the research. Government institutes are bureaucracies unable to adapt to the fast pace of change in agriculture, continuing their traditional programs in basic grain research even when the economic potential of new commodities would argue for a shift in research priorities.

Factors Related to the Potential of a Foundation

The USAID analyses go well beyond a critique of the public research and extension systems. They also point out the potential advantages that private-sector foundations may have in advancing the development of agricultural technology.

The most important attribute of the foundations, argue these analyses, is that they grant formal power to farmers and agriculturally related businesses to affect what the foundations do and how they do it. The foundations are attempting to solve the basic problem of making research responsive to the needs of the agricultural sector. A majority of every board of directors is from nongovernmental institutions, and some of the foundations also have advisory groups from the private sector. In some, USAID endowment financing is contingent on the contributions of private-sector counterparts. While this increases the funds available to the foundation, its other, equally important, purpose is to demonstrate that agricultural businesses are convinced that the organization will effectively provide the technology assistance they need. And with their representation on the board, they can help ensure that it does.

Second, USAID argues that the foundations can begin to develop the linkages within the technology system that are currently lacking, particularly improving research, extension, and education collaboration. One method of doing this is, again, through the board of directors, which often includes representatives from different institutions. A second method of integration is through the grants and contracts provided by a foundation. The organization can encourage proposals that involve collaborative work among institutions. It can also provide scholarship funds on a competitive basis to scholars willing to work in national research organizations afterwards. In Ecuador, the foundation is forging linkages between research and extension organizations by creating special units in the field which require both

researchers and extensionists. As an entity outside any one governmental power base, it can use its funds and activities to encourage better joint planning and execution of agricultural technology activities.

Third, a foundation can be much more flexible than any government institution. On the research side, grants and contracts can be awarded for short-term or long-term work, and the appropriate scientists can be contracted. If an expert in a particular specialty is needed, he or she can be sought within or outside the country and hired. There is no permanent, long-term staff with a defined set of research skills that limits what activities can be undertaken. Many countries are now experimenting with a wide variety of crops in an effort to diversify agricultural production; a flexible research system allows quicker response time to new opportunities and findings.

Flexibility on the administrative and financial side is just as important. Funds can be sought from all sources and go directly into the foundation's budget, rather, as is the case in most public systems, than into the general treasury. For example, the public research program in Guatemala, ICTA, established a foundation specifically so that it could accept private funds to carry out potato research. Numerous agricultural universities have also established foundations as a way of improving financial flexibility. In terms of leadership, a foundation can look both nationally and internationally for the trained management needed, offer competitive salaries, and not burden the managers with the administrative restrictions common to government organizations. Thus, the institution should be better able to establish priorities and maintain them and to plan and manage human and financial resources.

USAID analyses attribute two other positive characteristics to a foundation model. One is that a foundation will be "above the political process," and certainly apolitical itself. This reasoning is based first on the fact that the foundation director is not chosen by the minister of agriculture or the president but by a board of directors looking for a qualified research manager. By choosing staff, researchers, and research priorities on the basis of technical merit, the foundation can be assured of remaining outside politics. Representation on the board by respected international researchers will further insulate the foundation. This will end the common forms of state political intervention into the research system.

As the case studies demonstrate, however, the creation of the foundations has certainly not been free of politics. In some cases, they were initially linked to a specific faction, and it is not yet clear to what extent they will be able to divest themselves of those linkages. It is now clear that a board of

directors, even when dominated by private individuals, is not a guarantee that the foundation will be perceived as apolitical.

Finally, the foundation model would seem to provide a way out of the funding problems endemic to public-sector research in Latin America for the following reasons: First, whatever funds there were would be better managed.

Second, and most important, is the possibility of setting up an endowment that would assure stable, sufficient funding to the institution. So far, however, this has not been the general practice. FHIA in Honduras has not been able so far to persuade the government to release local currency generated from USAID food programs to use as endowment. Ecuador was given some local currency funds, but they are insufficient to provide much stability. The Dominican Republic foundation, with larger USAID counterpart funding and contributions from the private sector, is probably in the best financial position. In general, however, funding problems have not been resolved by creating the foundations.

To sum up the analyses, most began with a harsh indictment of the government's research and extension efforts. The criticisms noted that research budgets had fallen but that most of the failures of the system were due to weaknesses in administration and leadership. The organizations had failed to give a voice to the farmers and agribusiness groups who were their clients. Their weak financial position was made even more precarious by burdensome mechanisms of budgeting and fund dispersal. They were unable to set research priorities or coordinate research and extension activities. In contrast, the analyses justified the foundation model as providing flexible administrative and financial tools free from public-sector overregulation, as developing formal leadership roles for farmers and agribusiness, and as capable of developing linkages between the national agricultural research system and technology, as well as new outside sources of funding.

The Unfinished Analysis: Implications for Success

The justification for the research foundations is not complete, however. There are a number of issues that have either not been examined at all or only in a cursory fashion that will influence whether the foundations succeed in their objectives. Some of these issues predate the foundations, while others have been raised by their creation.

One of the most serious problems is the weakness of the economic and financial analysis of the prefoundation agricultural technology systems. In some cases (Jamaica and the Dominican Republic, for example) government research activities and allocations are not even discussed, as if irrelevant to improving the system. In others, there may be a general feeling that

government expenditures for research have fallen — but in no case is this accompanied by actual supporting data. There is simply no analysis of the governments' investment in research and technology-transfer.

This is in part a logical consequence of offering a new institution as the major remedy for difficulties in research and extension programs. But it has important implications for assessing responsibility for failure. While research budgets were falling in the 1980s, most of the current difficulties were attributed to problems of management, leadership, and politics, not to the macroeconomic difficulties faced by Latin American governments (beyond the control of research planners). The implication in the USAID analyses is often that if budgets are falling, it is because the government is cutting back its support for institutions it knows to be ineffective.

The importance of understanding both the rationale behind falling government investment and the importance of the budget itself in explaining the failures of the present system becomes clear as conditions improve. Will the government be willing to invest more? And will more money actually help? If the systems' decline in the past decade is due primarily to lack of funds, then the quality of research and extension efforts should be expected to rise as improved growth rates give governments the opportunity to increase funding to research — quality should rise regardless of improvements in the organization of the system. On the other hand, if quality of output is not directly related to budget, then the new money USAID is willing to put in through a foundation may be wasted. The foundations provide flexible mechanisms for by-passing the on-going systems — they do not include fundamental institutional reform of the systems. Concentration should in the first instance be on institutional reform, accompanied by making new resources available. This suggests that USAID's strategy of policy dialogue should have an important place in improving the agricultural technology system. Money should follow reform.

A second, related, weakness is that data are not collected on returns to agricultural research and technology transfer before decisions to invest money in the sector are made. Neither are such data collected before conclusions are drawn that the present system has failed. The single exception in USAID documents was in Peru, where USAID-commissioned studies showed that returns on both research and technology transfer for four basic grains ranged between 15% and 40%, depending on the commodity. At a minimum, this would be essential baseline information with which to compare the success of a new project. Awareness of the benefits of the research program may have been one reason why the USAID mission decided it could continue to support public-sector research in Peru.

In addition, the analyses look very selectively at the institutions involved in agricultural technology. Most carry out some analysis of research and extension institutions and a number focus some attention on marketing and export institutions. Except again for Peru, however, there is a no serious examination of, for example, agricultural education institutions, the dominant source of trained professionals in the sector. Finally, the foundations themselves create a new set of problems that have not yet been systematically analyzed. How will these new institutions survive past the USAID project that funded them?

There are three possible outcomes, each with its own set of issues. What the foundations look like — if they still exist — at the end of year 10 depends on which path is taken now.

One outcome is that the foundations will remain creatures of USAID projects indefinitely, unable to find other significant sources of support. There are some warning signs in this direction. One is the recent Winrock evaluation of FHIA in Honduras. It warned that the most critical problem of the foundation's future was the anticipated lack of funding. FHIA has been unable to interest other donors in giving large grants or contracts. Although the minister of agriculture sits on the board of directors, the overall relationship between the public-sector research program and FHIA has become competitive. The Honduran government has not been willing to release the local currency funds generated through USAID food programs that USAID would like to use to set up an endowment for FHIA. As a result FHIA currently seems unlikely to get either government funds or an endowment. While it earns some money through its research activities in bananas and plantain — where its initial expertise lay — it faces the same problems as its predecessor, United Brands. It will be difficult for it to capture the research gains it makes. FHIA's problems are one signal of difficulties to come throughout the foundation system. Parallels can also be drawn with the regional research institutes, and even with the international agricultural research centers: all remain dependent on international donors.

A second possible outcome is that the foundations will survive by becoming self-sufficient, through their investments and contracts, within a relatively short period. There are several considerations relevant to this outcome. One is that with the exception of the Dominican Republic, none of the foundations was established under this premise. The foundations work as research brokers to some extent, identifying key research problems and then using their funds (or funds solicited from other sources) to encourage researchers in the national system to work on those problems. They do not hire their own researchers, except in Honduras. While they may capture the administrative costs of their activities through overhead charges, this is not likely to be sufficiently high to ensure their survivability.

The route of self-sufficiency raises other disturbing dilemmas. Who will be the major beneficiaries of the foundations? To the extent that many of their activities must be profitable, the new organizations have to look at who has the ability to pay for their services. Within the private sector, this is not likely to be large agribusinesses, exporters, and processors. It is even less likely to be small and medium-sized farmers. The foundations' explicit mandate, however, usually emphasizes helping low-income farmers, which indeed is also USAID's mandate. The need to find remunerative activities will tend to bias the foundation system towards those agricultural clients who are better-off.

Is there a potential conflict of interest between the use of public funds (from USAID or local currency) and the search for self-sufficiency? For example, the El Salvadoran mission is exploring the possibility of the foundation taking equity positions in the firms to which it provides information on agricultural technology. It is not difficult to imagine a foundation giving information to farmers on a preferential basis if the foundation will benefit financially from doing so. Preventing the spread of technology, or at least delaying it, might be more profitable both to the farm and to its equity partners.

How will research priorities be established and enforced? Again, one of the chief criticisms of the prefoundation system is that priorities are continually expanded to please new client groups. The analysis of the Ecuador system, for example, criticized the government's lack of priorities, the result of looking everywhere for any available funding. It is not clear, however, how the new foundation will escape exactly the same problem. Under what conditions will the foundation say *no* to donors or those willing to pay for specific research activities? The question of whether and how to set priorities needs careful thinking. In the case of a "collaborative" foundation whose primary purpose is to improve the national system, it may in fact be less important to eliminate particular commodities and more important to figure out the most important activities to initiate.

The third possible outcome is that the national governments will in the end pick up the recurrent costs of the foundations. This is not an unreasonable outcome, given the public purposes of the foundations, which is to improve agricultural technology and raise productivity. Many of the activities of the foundations are explicitly to improve the linkages among public-sector institutions. They are nongovernmental only in the sense that a majority of the board of directors does not hold government positions. This leads directly, however, to the question of what the relationship between the foundations and government agricultural institutions is and what it should be. So far, there is ambivalence and inconsistency. The foundations are supposed to both bypass the system and improve it. They are often sharply

critical of the government — and in some cases, the planners are explicitly hostile to the government — yet they will have to live in the system in the long run and adapt to it.

At present, even when their aims are generally public, the foundations represent serious competition for national systems. They can pay much larger salaries (often four to five times the national rate) for researchers and are attracting many of the best from the national programs — thereby weakening these programs, at least in the short run. They are also looking for the same funds that would normally go to government research programs. In addition, they establish their own priorities, which may or may not coincide with the government's. They could become, with adequate funding, a parallel national program. This could be costly to small countries with inadequate scientific manpower under any conditions. More than any other issue, the sustainability of the research foundations depends on working out how the foundations will relate to the rest of the agricultural technology sector.

The future of the foundations seems very much in doubt. While this new approach was intended to circumvent severe institutional problems in the existing systems, the integration of the foundations into the rest of the agricultural technology system must be systematically worked out or they will be one more "innovative program" that lasts only as long they can maintain USAID interest and support.

CONSTRAINTS IN POSTHARVEST FISHERY RESEARCH PROJECTS

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Abstract

The lack of proper planning in research projects involving postharvest fishery technology (PHFT) has resulted in the failure of several fishery programs in developing countries. Planning the research involves identifying the numerous constraints that will impinge on both the research program and the transfer of the technology that develops from the research. In this paper, the authors have identified these constraints in the areas of resources, harvesting, transportation, processing, and marketing in the fisheries sector. They are part of the system of interrelated environmental, social, cultural, economic, technological, and political factors that can radically affect the success of the applied output of any research.

Introduction

Projects for commercialization of seafood in developing countries often fail to achieve their intended goals, and this lack of success has hindered the development of good research programs. Those programs that do exist are, for the most part, underfunded, which, in itself, contributes significantly to their failure. Clearly, commercialization of seafood requires an adequate base for implementating applied research. In order to do this, however, it is necessary that the research must fit the system to which it will be applied — it must be appropriate. The economies of developing countries cannot afford inappropriate, expensive research programs, regardless of whether they are funded by grants, loans that must be repaid, or local funds. As a basic consideration, monitoring and evaluation of the research program must include making sure it is appropriate to the entire system within which it will be applied.

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When we think of research in commercialization of fish, we usually think of research aimed at converting fish into some kind of marketable product (e.g., canned, dried, frozen, etc.). It is, however, frequently necessary to conduct research on other aspects of commercialization such as preservation in distribution systems, administration of vertically integrated firms, product acceptance, etc. The problem is that research tends to be focused on only one part of the entire system.

This can be the result of the disciplinary orientation of the stimulator of the research; e.g., a recently returned Ph.D. in food science, or marketing research, or transportation systems, etc. It does not even have to be a recently returned graduate — sometimes even development agency "experts" are narrowly driven by their own area of expertise, assuming it is sufficient to solve perceived problems. Hence, safeguards have to be built into the systems that plan and make decisions regarding research in postharvest fishery technology (PHFT) if the research is to be appropriate.

As a first step, it will be instructive to describe two projects, one large scale and the other on a smaller scale to determine differing and overlapping constraints. We will then identify these constraints so that future projects may address these issues in the planning stages to determine their operational feasibility.

Fishery Development Projects

During the later part of the '70s and into the '80s, several fishery projects were implemented that coupled increasing harvests of seafood with the increase of domestic consumption of fresh fish and fishery products. A general theme that developed in these projects was to improve the nutritional status of lower-income populations with the production of low-cost fish products. In one program in a Latin American country, a commercialization subproject was integrated into a broader multimillion-dollar project that stressed the industrialization of the fisheries in the country. The marketing subproject goals were as follows:

1. the establishment of retail centers and wholesale distribution centers to increase the distribution of seafood products;

2. the marketing of fresh, frozen, and processed fish into new areas as well as the introduction of new products into established areas;

3. the increase in consumption of fish in the country especially among the rural and urban poor.

Facilities for distributing, freezing, and processing the fish were established through a newly formed government corporation that included retail and wholesale stores and was vertically integrated from harvest through marketing. Research in terms of product development and consumer preference was important for the production of low-cost foods targeted for the lower-income populations.

Implementation of the project demonstrated that there would be problems from the beginning. The locations of retail and wholesale stores were poorly planned and few marketing incentives were given to the stores' personnel. Supplies from the fleet were inconsistent as financial problems of the parent company eroded the business confidence of both fishermen and middlemen who then distributed their fish through other buyers. The production of new products was hindered by problems in scaling up from the pilot plant to commercial operation.

Product quality also suffered because researchers were poorly qualified in the area of food science and product development. The market research was poorly run and only done in large urban areas. Poor coordination between the integrated segments of the overall project assured the failure of the project's main goal, which was improving the nutrition of the general populace by increasint the availability of inexpensive fishery products. The net result was that the retail and wholesale centers were closed within two years because ofthe lack of sales. Losses became so great in the commercialization subproject (up to US$ 6 million per year) that the parent company's other operations were adversely affected as well. The overall impact was a negative one for the fisheries because it drained their financial reserves and eroded the general public's confidence in fishery products produced within the country.

A smaller, but also problematic, project involving sharks was carried out in another Latin American country. Adjacent ocean waters were teeming with sharks which were not captured or utilized in any manner by the local population. Fishery experts felt that this was an opportunity to develop a project that would take an underutilized resource and turn it into food for the population. An international development agency, in cooperation with the country's fishery department, implemented a project designed to convert shark into an acceptable product, which is not simple.

Errors in postharvest handling frequently result in an unappetizing product, and in some areas there are cultural values against eating sharks (Adams 1986). People in the country stated that they would not eat sharks because sharks eat people. This folk wisdom was underscored by the fact that when one of the authors arrived in the country at the beginning of the project, there were newspaper articles concerning fishermen who were

complaining about the abundant sharks that were, at times, bumping their boats and causing much alarm. Stories circulated about fishermen being attacked and sometimes killed.

The project, however, was apparently well designed. It involved development of a product demonstrably acceptable to the local population, packaging and renaming to enhance its acceptability, and televised programs concerning its preparation since it was a dried product and unfamiliar to the local population. Television was an appropriate medium for advertising the product. Most of the country had electricity, and in the evenings people would gather at local shops to watch television. Even in areas not yet served by electricity, shopkeepers aware of TV's attractiveness would operate a set using a small generator, which also supplied the shop with light.

At the beginning of the televised educational program, however, some minor errors were made. The cooking demonstrations were done on electric ranges, and most of the rural population cooked with wood or charcoal; hence, cooking techniques and times were inappropriate for most of the target population. The project was flexible, however, and carried out continuous monitoring, so the problem was noted and corrected. The product gained consumer acceptability, and the people in the fishing community learned to operate the drying and packaging equipment.

The project seemed to be viable when the development team left the area. The problems that developed involved inputs to the postharvest processing and distribution scheme. When the project team was in the country, a project-supplied "expert fisherman" harvested sharks for processing, using a vessel somewhat larger than the local craft. Local fishermen, however, did not target sharks, and after the project team departed, local fishermen still did not capture sharks. This was due to various factors, including a lack of knowledge concerning shark fishing and a fear of the animal. Since fishermen in some neighboring countries harvested sharks using relatively small vessels (some using dugouts no more than five meters in length), this problem had not been anticipated by the project personnel.

Hence, a potentially useful project died because of a lack of attention to sociocultural factors affecting inputs. Sharks were traditionally unacceptable as food; thus, the fishermen had no reason to develop shark fishing methods. Additionally, sharks were perceived as very dangerous animals, reinforcing the reluctance to harvest the species. Because sharks are sometimes caught accidentally when other species are targeted, and because shark are harvested in other Latin American countries, project personnel assumed there would be an adequate supply of shark for the processing plant that they developed. These assumptions were faulty.

These examples highlight an important point about PHFT research projects — the processes and products being researched can not exist in isolation. They are part of a system of interrelated factors (environmental, social, cultural, economic, political, etc.), any one of which can radically affect the success of the applied output of the research. Hence, it is essential that we have an understanding of the matrix of factors that potentially affect project success *before* spending scarce resources on PHFT research in a developing country.

To some this may sound like beating a dead horse, but we have witnessed enough failures in PHFT projects to assume that either this is not general knowledge or it is being ignored at the expense of scarce resources in developing countries. As will be shown, fishery projects are especially problematic due to the characteristics of the resource and the product. Hence, using the foregoing projects as a starting point, we would like to identify the complex of factors influencing applied success of PHFT projects and suggest some methods for accounting for them in project design.

Diagnosis of Projects

In the diagnosis of the larger project, we need to look at four different areas: the planning, implementation, on-going monitoring, and evaluation. The planning of a project of this magnitude is the most important phase of the overall project itself. There were several constraints that should have been recognized from the beginning. The planning committee itself consisted of engineers, biologists, economists, lawyers, and politicians but was deficient in terms of technologists and marketing analysts. Very little was known about the economic factors influencing seafood consumption in the country. No research had been undertaken to estimate gross characteristics of seafood demand such as own-price elasticities.

Predicting the effect of increased availability and deciding what fish products should be developed required an understanding of the patterns of perceptions and preferences for these products. There were few qualified personnel who could undertake these tasks, and the planning committee relied on consultants from outside the country.

During this period there was great activity in the fishing industry worldwide. On-hand experience in the marketing of seafood, however, had mainly come from developed countries involving cold-water fish species from the Asian region. Little experience in marketing had developed in the Latin American region, which traditionally consumed low amounts of fish. Outside consultants tended to extrapolate from other regions or theoretical models which were accepted as workable by both the funding and the executing agency. At the time, no research to gather accurate base-line data had been

proposed as methodologies for doing so were poorly described. Consequently, unrealistic goals such as "improving the level of national nutrition" and "fabricating inexpensive fishery products" were incorporated into the work plan. Goals such as these were later attacked in the popular press when it became obvious that they could not be met.

Failures during the implementation stage were due to both inadequate planning and lack of proper integration into the other sectors of the project. The hinge-pin of a project of this nature is the supply of raw material for processing for and distribution fresh. A significant part of the project involved the construction of vessels to increase the size of the fish harvest in order to supply the stores. Because of delays in building the boats, many of them were not on line by the time commercialization was to begin. And those that were constructed were not utilized to their capacity by the fishermen because of design flaws or the fishermen's unfamiliarity with the fishing techniques required.

Fish were available from the small-scale sector because it had gone through a different strengthening program. However, the financial status of the parent company was such that monies were frequently not available to purchase fish in large quantities, nor were the fishermen willing to sell to the company on credit since other buyers were available.

The retail stores themselves were poorly operated. Location was a problem as some of them were placed in coastal towns where fresh fish markets were already established and new markets were unnecessary. Locating the markets in the largest municipality of the country was ill-advised because the city was going through a major traffic rerouting during the same period, and several of the stores found themselves on major thoroughfares that prohibited stopping and parking.

Few incentives were given to salaried employees, and they in return showed little interest in the stores or promotional sales. Attempts to compete on the open market were strongly resisted by fish sellers in the private sector who were supported by the Ministry of Commerce and Industry.

Once it became obvious to the executing agencies that the marketing of fishery products entailed much more than they were prepared to handle, the project received less and less attention. For the sake of the loan program and in order to demonstrate that a proper effort was being made in the marketing sector, more emphasis was given to PHFT research and the development of inexpensive food products.

This suffered many of the same problems as the original marketing program. Personnel were not adequately trained to do the necessary technological and

socioeconomic research. Technology transfer in terms of equipment did not occur because the tunnel freezers purchased to produce the final product were too sophisticated and often broke down, generating expensive repair and maintenance costs. Market studies for the product were poorly done and did not include the rural poor who were targeted in the original research plan.

The question arises, Could this have been prevented by proper monitoring and evaluation? Although the overall project would have failed anyway because of problems in the planning and implementation phase, certain components would have fared better if proper monitoring had been carried out during the program. The failure to write verifiable reports, to provide fiscal accountability, and to report sales systematically did not allow the project any flexibility. This lack of flexibility can be looked upon as a severe limiting factor in seafood marketing, which is dynamic and subject to monthly fluctuations. Many of the initial problems in the PHFT research project could have been dealt with more expeditiously if the reports had been available and had had scientific merit.

The diagnosis of the shark project is relatively simple since it was so nearly successful. For the most part, planning was adequate. There was apparently a sufficient supply of sharks — a resource that was unutilized. Market research indicated that dried shark would be acceptable if the name were changed, the drying and packaging technology was well developed and appropriate, and a channel existed for distribution and marketing.

This basically good planning facilitated implementation, and monitoring was adequate enough to determine that the initial extension programs on television were using inappropriate cooking methods, so the program was changed. For some reason, however, monitoring di not pick up the fact that the local fishermen were not capturing sharks; hence, a problem existed at an unexpected point in the chain from the sea to the consumer — the fishermen did not know and did not want to learn how to capture sharks. Although the planning was basically good, it failed to include a provision for determining whether or not local fishermen could maintain the needed level of supply for the processing, distribution, and marketing system developed by the PHFT research.

Identification of Constraints to PHFT Research Projects

The examples given above indicate that a problem anywhere along the chain from the resource to the consumer can result in the failure of a PHFT research project. This observation suggests that it would be useful to develop a diagnostic methodology that would deal with each element along this chain, which includes (1) the resource, (2) harvesting, (3) the transportation,

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(4) processing, and (5) marketing, which includes the consumer and is shown in Figure 1.

Resource →	Harvest →	Transport →	Process →	Market
1. Endogenous effects 2. Exogenous effects 3. Sustainable yields	1. Fishermen's attitudes 2. Ice, off-loading, & storage 3. Tropical environment	1. Mode of transportation 2. Variable supply 3. Established distributional chain	1. Human resources 2. Production costs 3. Quality control 4. Appropriate technology	1. Traditionalism 2. Lack of analysis 3. High cost of fish

Figure 1. Postharvest fishery research constraints

The following sections identify constraints to the application of PHFT research projects which are associated with each of the elements in the chain.

The Resource

In contrast to most food-technology projects, those based on capture fisheries are dependent on a highly variable supply that is difficult to predict. Catches vary from day to day, month to month, and year to year. Some variations are due to local weather, which influences fishermen's fishing activity; others are due to variations in the locations and quantities of the fish stocks, resulting from climatic/oceanographic changes (e.g., El Nino), periodic migrations, pollution, and the effects of fishing activities on the stocks. Applied aspects of PHFT research must be planned with these variations in mind.

Perhaps one of the biggest errors regarding this resource that a PHFT research program can make is assuming that an observed or reported abundance of targeted species can be projected into the future. It has become quite clear that fish stocks, especially tropical reef fishes, can be rapidly depleted by increased harvesting pressures (Roedel and Saila 1979).

A research program aimed at developing systems for processing, marketing, and distribution of a given species may result in a technologically attractive development scheme that seems both economically and socially feasible. The project could be implemented and operated successfully for a year or two, only to fail after the stocks are depleted to the point that their harvesting is no longer economically feasible. The bottom line is that it could be wasteful to conduct applied PHFT research on a species without first obtaining information concerning the status of the stocks. This information should include a projection of the sustainability of the resource under the level of exploitation required to fulfill potential project objectives.

The Harvesting Sector

A basic consideration with respect to the harvesting sector is whether or not it can support the demand projected to result from the research. A big industrial fleet targeted at the desired species and vertically integrated into the entire harvesting, processing, and marketing system might be able to provide sufficient inputs as long as the workers continued to work and the resource remained at an appropriate level. But the output of numerous small-scale entrepreneurs in a developing country's fishing industry is a bit more difficult to predict.

Typically, the small-scale fishery in a developing country is composed of a number of independent boat owner-operators who target species that they have the knowledge and gear to harvest and for which they can receive the best prices. They are businessmen — they will change target species if their calculations tell them they can afford the switch and will have a greater return for their efforts. An outside expert's demonstration is frequently insufficient motivation for such a switch.

Assumptions concerning the production of raw materials by the harvesting sector must be carefully examined (e.g., the shark project), especially if the species has previously been unexploited or "underexploited." There are frequently social, cultural, and/or technological reasons for traditional levels of exploitation.

Sometimes the proposed PHFT requires a quality of fish not available through traditional harvesting methods. For example, in tropical waters the fish frequently start to decompose before they are even taken from the net. Additionally, these fisheries often do not use ice; hence, fish reach the shore in a less-than-fresh state. While this may be adequate for the traditional processing (if any), distribution, and marketing systems, it may not be acceptable for a system resulting from the applied research.

PHFT research that extends the shelf-life of seafood will have minimal impact unless extension training occurs at the beach level. This has been largely neglected in the past and several fishery development projects have failed because training was aimed at middle management and not at the fishermen. It is then necessary to ask if changes to insure acceptable quality are feasible given the traditional situation: Can or will the fishermen pull their nets more frequently? Is ice available, and will the fishermen use it? (Will it reduce the vessel's payload?) Can they afford refrigeration or ice, etc.? If not, the fish supplied will be of lower quality than that assumed by the applied research — making the research findings inappropriate and suggesting that the PHFT system developed from the research would not produce the expected products.

The Transporting Sector

This sector involves all those involved in moving both the raw material and the processed fish product. Small-scale fishing communities differ with respect to the development of this sector. In some, fish is unloaded from the vessel and sold directly to the consumer by the fishermen. In others, retailers meet the vessel and take the fish to their marketing locations by foot, bicycle, or motor vehicle of some sort. In still others, middlemen (wholesalers) transport the fish from the beach to the retailers.

Some fisheries have a very complex division of labor, which includes specialists carrying fish from the vessel to individuals who transport the fish to processors or middlemen, who then hire other transporters to take the fish to the retail or larger wholesale markets. It is obvious that for a specific PHFT technology to succeed, it must have an appropriate link (in terms of size and handling) with the harvesting sector and the markets. With respect to size, it must be capable of handling the necessary supply, and the handling must be adequate to deliver an acceptable product to the marketplace and raw material to the processor. Changes deemed necessary must be technologically, economically, and culturally feasible.

The Processing Sector

Research must pay attention to aspects of the existing processing sector. This is especially true if the applied research is directed at replacing or improving traditional techniques. The applied research must be influenced by the abilities, both physical and intellectual, of those presently employed in processing. For example, are the techniques too complex for existing educational levels? Are the physical demands of operating the equipment beyond the abilities of those traditionally employed in the sector?

The research must also be influenced by the projected costs of the materials and equipment involved. Will the process developed demand new equipment that is beyond the present purchasing power of traditional processors? If yes, will there be access to loans or subsidies? These and other factors of importance in the transfer of new processing technologies (Morrissey 1988: 250; Pollnac 1978) should be routinely evaluated as part of developing PHFT research programs involving the processing sector.

The Marketing Sector

Marketing in small-scale fisheries ranges from fishermen directly bartering surplus catch for other goods (e.g., rice or some other agricultural product) to complex systems involving numerous middlemen (buyers, sellers, etc.) spread over a wide area, including large urban and widespread rural

markets. Applied PHFT research must have a clear understanding of the operations and functions of these existing marketing systems. If the research involves improvement of quality, some of the changes will undoubtedly involve participants and practices in the existing marketing system.

As with the analysis of the processing sector, it is important to be sure that the proposed changes resulting from the PHFT research are technically, economically, and culturally appropriate. Changes as apparently clear-cut and simple as building a new, technologically sophisticated marketplace in a slightly different location can fail if they conflict with traditional behavior patterns (Pollnac 1988: 250). In sum, the market has participants and users who must accept the outcomes of the PHFT research if it is to be a success.

This leads naturally to the next sector, the consumer. The consumer is at the end of the chain of potential impacts of PHFT research. When this research clearly involves product development, it usually includes product testing among potential consumers. Product development and testing is a highly developed field, and it is only necessary to note that if the results of the research are to be applied, the same care used to develop new products in our own society must be used in developing countries.

In general, fish is no longer an inexpensive food item. The processing of fish into such items as minces or fish sausages, while technologically feasible, would place most of these products out of the financial reach of the average consumer. It also diverts research efforts away from more basic problems such as methods for direct utilization without processing. Applied PHFT research must always keep the consumer in mind in terms of purchasing power, taste preferences, preparation techniques, and social factors involved in the acquisition of fishery products. When a research project is proposed, it must show that these considerations are primary and are to be assessed prior to committing funds for the actual research.

Conclusion

The purpose of this paper is to make a very simple point: research is costly; hence, more care needs to be taken in the planning, implementation, monitoring, and evaluation of PHFT research projects in developing countries.

Planning, however, is the key. It is during the planning stage that one determines the fit of the research to the existing system. It is also during this stage that the parameters for monitoring and evaluation are established. Figure 1 illustrates what we need to consider to ensure the potential applicability of an applied PHFT research project. This may look like an enormous task, but it is not all that difficult.

Perhaps the most expensive task will be evaluating the available resources, but some quick and simple methods exist to give some assurance that target stocks won't disappear during the first few years of exploitation at a given level (Pauly 1984: 325). Examining other potential constraints involves a minimal investment of time and money in contrast to the cost of the research and its potential benefits if successful.

The point is to not go blindly into a research project that will lead to relatively high expectations that will be destroyed by some obvious (in hindsight) constraint that was overlooked in the planning process. This can only occur if the review of proposed PHFT research projects requires that potential constraints be identified.

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NETWORK ANALYSIS AND NEW AGRICULTURAL TECHNOLOGY: THE ANALYSIS OF SOCIAL STRUCTURE AND DEVELOPMENT USING RELATIONAL MATRICES

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Abstract

The methods of social network analysis have been subjects of great interest and extensive development in recent years. Wider use and further development of these methods could lead to work on economic organization and economic process that is, more strictly, formally comparable from case to case and from study to study. This paper details some of the fundamental, matrix-based procedures used in network analysis and interprets them in terms of culture theory and social structure. An example is developed in which the economic structure of a farming village is analyzed using block-modelling techniques and in which principles of economic culture in the village are inferred from the modelling results.

Introduction: Social Structure and the Nature of Cultural Continuity

The fundamental concepts of social structure and of culture are widely known and widely used. They are, first, that relations among individuals combine into systems, and, second, that both these relations and the systems they form become expected and become objects of psychological attachment.

It is common to look at social structure as a constraint. It is just as common, however, to find that when social structures are tested, they are capable of reorganization and adaptation, while still retaining a fundamental continuity with the past and a strong integrity with it. The paradox is solved by

changing the basic assumption — by ceasing to regard social structure as constraining. Instead, it is regarded as enabling, and adaptation and manipulation are assumed. Freed by this assumption, we focus on how adaptation occurs and what the nature of continuity is.

Individualistic endeavor, mediated by the individual's goal-directed, instrumental use of culture and of social relationships, is a primary force in adaptation as well as in the ordinary conduct of daily life. Even in those societies that appear to be the most unchanging, individuals make their own strategies and seek their own paths through the network of social relations, in order to reach their own ends as they see them. Relationships established and renewed by individuals, seeking their own benefit, go to constitute the total structural system at its most basic.

If for many individuals these networks of relationship, with their accompanying goals and strategies, show a similarity with each other and with the networks of the past, then cultural institutionalization of the similarities should be expected. The initial source of such patterns is substantive, real relationships of social connection and economic life. Once established, however, the patterns themselves can influence expectations and strategies; thus, they can act as forces for continuity. Some methods useful for tracing such continuity, and for understanding its usefulness and its limits with regard to substantive economic life, are examined in this paper.

Culture Is a Set of Means for Ends

The principle of cultural relativity does not only state that people learn (with equal ease whatever their parentage) any culture they are brought up in, it also maintains that if given the chance, most cultural systems can be turned by their members to the solution of most organizational problems. Learned patterns of interaction represent an important form of human capital. These patterns and the rules for their combination are able to persist and to show continuity from one substantive situation to another, because in their evolution they have developed flexibility. If the culture makes a certain set of responses or relations primary, then balancing responses are usually available as well. Limits to adaptation often are imposed less by culture itself than by the possibilities inherent in large or small scale, or by the time available to create adaptations and new complexity. In different systems, the sequences and rules of relationships employed will be different, but the economic outcome can be the same. This principle lies, for example, behind the repeated observation that farmers in peasant villages use their traditional factors of production with full allocative efficiency according to their situations and that they seek new factors of production as well (Schultz 1964).

Analytic Goals

The fact that cultural patterns have widespread, adaptive utility means that we need to understand how they arise and how they are applied. What are their essential characteristics? If an area of culture undergoes great change of form and function, and yet appears to share an integral continuity with the culture of the past, what is it that is shared? If social organization and culture are not constraints but enablements, how is the power of enablement realized? What sequences of relationships are the important ones, in what overall patterns appearing in different times and places? The following sections discuss methods for the identification and analysis of patterns in social and cultural systems. A description of methods is given first, followed by an application to a particular case and a short discussion of bibliography and further possibilities.

Tools for Analyzing Social Structure

The fundamental idea supporting the methods discussed in this paper is of a *relational matrix*. This is an arrangement of rows and columns, labelled for actors or groups in the society being examined. Rows and columns have the same labels: if row 1 is for person *A*, then column 1 is also for person *A*. The matrix records ties of some sort in a society, ties that are extended from one person to another. Recording the ties in a matrix of this type means that the rows will show the cases in which one person extends a tie to others, and the corresponding columns will show the cases where the same persons receive ties from others. A tie can be defined to be any sort of relationship one wishes to investigate.

In the system of binary notation used in Figure 1, the numeral 1 indicates the presence of a tie and 0 indicates its absence. This notation works equally well whatever the nature of the tie may be. The relationship that is extended and which links one person with another may be conscious or unconscious, positive or negative. It may be simple, in the sense of having only one identifying aspect, as in the case of a person recognizing another person as a resident of the same community. It may be complex, as in the case of a farmer who recognizes another as a member of his own community and who also recognizes him as an expert in a particular line of crop production.

(row extends tie to column)

0	1
1	0

Figure 1. Ties of friendship extended symmetrically between two persons

It is easy to see how a process of defining more and more complicated ties could proceed. With the expert farmer who is also a resident of the first farmer's village, one could add the stipulation that the expert is also recognized as a member of a group of lineages whose members have usually owned only a middle amount of land. In order to be useful, however, there must be some compelling logic that explains why all these aspects should be joined. It does little good to add too much circumstantial detail.

It is better to search for a simple tie that appears to act as an independent variable, helping the observer to explain why several characteristics seem to appear together again and again. Both regularity and effect are keys. Structurally important ties are likely to be widespread and to occur in particular, definable contexts. They are also likely to be predictable not only in their occurrence but in their consequences.

There is considerable flexibility and subtlety possible in the description of a society using matrices according to these rules. The examples in Figure 2 illustrate some of the possibilities for a society with two main groups.

These are only four of the sixteen logical possibilities for a two-group society.

(row extends tie to column)

01	10	01	11
10	01	01	00

Figure 2. Example matrices for four societies, each containing two groups

Interpretation of the figures depends upon the definition we provide for the tie being examined. If the tie is one of friendship, then in the first matrix, the members of groups one and two extend this tie symmetrically to one another. In the first matrix, however, they do not recognize friends within their own groups. In the second matrix, friendship for both groups is only internal. In the third matrix, the first group extends ties of friendship to the second, but the members of the second group recognize only one another as friends.

Instead we might interpret the matrices of Figure 2 to represent one group's engaging the members of the other in employment at daily wages. In this case, we can see that there are different implications than under an interpretation of friendship. We assume that employment at daily wages is a low-ranking, relatively unadvantageous job in relation to other possibilities. With this assumption, the first matrix implies an egalitarian situation and

the second implies division but not stratification. Matrix three implies stratification, with the first group in an advantageous position. Matrix four might imply incipient or less extreme stratification. Because they show daily wage employment by own-group members, matrices two, three, and four all imply some degree of group-internal stratification. In real cases, all of the patterns in Figure 2 would represent situations for investigation, to determine causes and consequences.

Manipulating Matrices

Square matrices of this type are sometimes referred to as sociomatrices. Operations on such matrices provide further ways to model social reality, and further possibilities for great flexibility. Textbooks providing an introduction to linear algebra (e.g., Kemeny et al. 1966) provide descriptions of the basic operations: matrix addition, subtraction, transposition, and multiplication. Not only dominant trends, but nascent or submerged characteristics can be depicted and can be compared formally with each other. The rules of matrix multiplication mean that the product of two or more sociomatrices shows network links from one person to another: friends of friends (Festinger 1949).

It is worth noting that construction of a useful relational matrix depends upon a great deal of judgment, of the kind that must come from fieldwork or from a thorough knowledge of primary sources. Particularly important are the identification of significant types of ties and the identification of the groups or individuals whose social systems are to be modelled using these ties. Once the need for well-founded and theoretically informed judgment has been satisfied, so that particular ties or combinations of ties can be defined and can be hypothesized to be meaningful for particular populations, modelling can proceed further.

Block-Models

In recent years one of the most successful methods developed for matrix-based analysis of social and cultural systems has been block-modelling. As White and his colleagues (White et al. 1976; Boorman and White 1976) emphasize in their papers outlining this methodology, block-models are particularly important for their ability to give empirical, definable shape to the important sociological concepts of role, position, and structural equivalence. At the same time, block-modelling is particularly well adapted to work with multiple types of ties and to work with large populations. Algorithms have been developed in computer languages, including APL, BASIC (MacEvoy and Freeman 1987), and FORTRAN to carry out the calculations involved, and are widely available.

A *block*, in the definition of this modelling system, is a group, all of the members of which send and receive ties according to the same overall pattern. The overall behavior of the members of one block towards the members of another block constitutes a *role*, and membership in a block constitutes a *position*.

In order to identify such blocks, and the relations among them, the analyst begins by using appropriate methods (including field observation and questionnaire analysis) to identify ties that appear to be important for the society being examined. A binary matrix is prepared detailing the ties. Rows and columns refer to the same individuals. Groups may be substituted for individuals if this makes the analysis more manageable or if a rigorous comparison of the ties of groups is the goal (in this case, the analysis will identify blocks of groups, instead of blocks of individuals).

The binary matrices to be examined should be "relatively sparse," in the words of the method's developers, with a reasonably large number of unfilled, blank elements containing zeros. If the system of relations is to be blocked for a single type of tie, analysis can begin immediately; if several ties at once are to form the basis of the blocking, then the matrices for all of these ties must be "stacked." This only involves writing them as one long matrix, one square matrix immediately below the other, instead of keeping them separate. The rows of the stacked matrix, if three sets of ties are being examined for 10 people, for example, will number 30; there will be only 10 columns, the same number as for each square matrix alone.

Advantages from stacking matrices for different ties may accrue when two or more sets of ties together provide a better measure of some phenomenon than either does alone. An especially important case of this situation is when two sets of ties, as for liking and disliking, are clearly mutually exclusive, so that if they are stacked and analyzed together they can be expected to produce a blocking that identifies the same social divisions from two different perspectives.

The first analytic step is the correlation of the columns with each other: column 1 with column 1, column 1 with column 2, and so on. This is repeated until the correlation coefficients for all combinations have been obtained in order. These coefficients are entered, across the rows, as the elements of a new matrix. The new matrix will be square and will be the same size as the original matrices for separate ties. Values on the diagonal, which show correlations of columns with themselves, are ignored in subsequent steps.

The columns of this new, square matrix are correlated in the same manner, and a third square matrix of the same size is prepared from the results. After several iterations, the process approaches a limit, with all of the correlation

values moving toward 0 or 1. At this point, the algorithm searches for a permutation vector — an order for rearrangement of the rows and columns — that will assure that as many zeros as possible will be grouped together in the final matrix. (The algorithm described is CONCOR, see Breiger et al. 1975.) The first split will permute the matrix so as to display two main blocks; if the results appear unsatisfactory, the process can be continued and either or both of the blocks can be split again or several more times. The results are trivial, however, if the process is continued indefinitely: if it is carried on too long the final blocks will be based only on the single individuals of the original matrix.

Reordering the original matrices according to the overall permutation vector obtained, with rows and columns in the same new order, should reveal areas of relative density and relative scarcity of ties at the row-column intersections of blocks with each other. The term *block* is used to refer to these intersections as well as to the groups of individuals or other entities associated by the correlation and permutation procedure.

A process of simplification is followed to emphasize overall structure in the results. In this process, the density of ties in the matrix as a whole is calculated, and the figure for overall density is compared with the densities of ties at the block intersections. The analyst may choose a cutoff point according to judgment, deciding that blocks whose density is below this cutoff level will be counted as zeros, while blocks at or above the cutoff level will count as ones. Blocks with densities equal to or above the mean, for example, could be ones, and those below could be zeros; alternatively, the cutoff could be set at 1.5 times the mean density, or at some other level. A simplified *image matrix* can be prepared on this basis, in which rows and columns refer to blocks rather than to individual persons or groups. Overall social structure is often much more clearly visible in such a block-model image than in the original matrix of ties or even in the blocked matrix.

In choosing a cutoff density to use in constructing the image matrix, much depends on the analyst's judgment and on the distinctions that are desired to be brought out; at the same time, all the information from earlier steps is available in reserve, so that reworkings and comparisons using different interpretations or cutoff points are possible. Comparisons with some formalism, both within the society and across societies, are made possible. The analysis is explicit, from the initial definition of the ties used and on through the permutation to the final preparation of the image matrix. Because of this explicit character, it is possible to see and to describe with some clarity what differs and what remains the same.

A Block-Model Example

The following example shows the process of block-model construction for economic relations in a situation involving farming and market development of some complexity. The case is from India, from a 1957 ethnography by F. G. Bailey. The situation recounted in the book is one of flux. In the India of 1952-54, when Bailey's field work was carried out, the influence of a centralized state administration and of a market economy were entering areas in which local autonomy and an old pattern of group stratification had been the rule. Bailey details the situation in a village named Bisipara in highland Orissa. One group of related households (1, in Table 1) whose members had controlled all the land in the village in the past, were losing much of their position to those with cash incomes. Groups 2 and 3 had begun in the village area as distillers but had left this business and had moved into the higher-

Table 1. Income and Population in Bisipara

Group	Percent share of land income	Average annual paddy per capita*	Percent of village population**
1	28.2	1.2	19.3
2	10.0	1.2	6.7
3	12.5	5.3	2.0
4	1.7	1.6	1.0
5	0.8	0.7	1.0
6	1.25	0.3	3.4
7	0	0	1.0
8	0.13	0.1	1.0
9	1.0	0.2	4.6
10	1.0	0.7	1.0
11	0.75	0.4	1.4
12	1.0	1.0	0.8
13	2.6	2.8	0.8
14	0.6	0.2	2.6
15	0.5	0.4	1.0
16	20.5	0.7	21.7
17	3.0	0.4	6.0
18	0.75	0.2	3.8
19	0.25	0.1	2.7
20	12.2	0.6	16.5
21	0	0	0.2
22	0	0	0.1

Source: Bailey (1957: 49).
* As proportion of annual adult requirement.
** Age adjusted to adult equivalents.

status position of merchants, where they were becoming quite well off. As might be expected, various new factions and rivalries reflecting changed economic conditions were forming. If we assume that social structural connections are being used by the people of this village to adapt to these new possibilities and pressures, and to create them as well, it would be useful to understand their articulation in some detail and yet in clear outline. Block-modelling can help us to obtain such a view.

We can focus on the economic situation as a starting point, since it is the economic situation that is being manipulated by the members of the society. A block-model of the economic situation should give us a grid to use to understand the various distributions and sequences of ties arising as the villagers go about their daily work and advance their individual strategies. The economy of the village is based on irrigated rice cultivation, and on page 49 of his book Bailey provides a table that details the overall group shares of income from rice land owned or operated. In addition, he reports the average annual paddy (unhusked rice) income per head, also by group. The information on group and per capita income is particularly interesting because it provides relative standings based on the fundamental productive activities of the village. Examination of the table indicates that some groups such as 3, with their substantial cash income from trade, consistently appear to be better off than others. The situation also appears to be one of considerable intergroup economic complexity.

We would like to be able to say more than a simple inspection of the table allows, however, and we would like to do so with strong backing. One way to put additional order into this situation, in which there are 22 separate groups of households and in which the two measures of income are not perfectly correlated, is to consider the position of each group relative to each of the others. Relatively higher or lower income can be entered as binary relations of dominance (1) or subordination (0) in a matrix of 22 rows and columns, and the ties thus recorded can be analyzed using the block-model algorithm described above. On the assumption that analysis of relative land income and rice income together would probably imply more about change and about similarities and dissimilarities among groups than if only one relation were analyzed, matrices were prepared for dominance on each count. The two matrices were then stacked and were blocked together.

Figure 3 shows the sequence of derivation of four blocks. The numbers shown are those of the rows of Table 1; the same order given in Table 1 was used in construction of the relational matrices.

The algorithm first divided the 22 columns into two blocks, as shown in the second line of the figure. Inspection of the reordered matrix suggested that there was potential for a finer division with more pronounced zero blocks.

1 2 . . . 22

1 2 3 4 5 6 10 12 13 16 17 20 7 8 9 11 14 15 18 19 21 22

1 6 16 17 20	2 3 4 5 10 12 13	7 8 19 21 22	9 11 14 15 18
(Block 1)	(Block 2)	(Block 3)	(Block 4)

Figure 3.
Derivation of four-block permutation for a block-model of income in Bisipara

When each of the first two blocks obtained was split in its turn, the four blocks in the last line of the figure were obtained.

Figure 4 shows the matrix of rice income domination, permuted according to the blocking above. A density matrix and an image matrix are also shown. The cutoff point chosen for the image matrix was one that seemed natural, given these block densities: there is a wide gap between those blocks at or just below the mean density for the matrix as a whole, 0.49, and those blocks with a density of between 0.80 and 1.00. Because of this gap, only the higher-density blocks were recorded as ones in the image matrix.

The modelling process has, in effect, separated the 22 groups into four categories, each category having different overall economic relations with the others. Reference to Table 1 and to Bailey shows that the major agricultural groups have been placed in block 1, while those whose members are both agriculturalists and merchants are in block 2. Block 3 is marginal, in terms of its relations to the major crop, while block 4 appears to represent a sort of lower middle class in terms of rice income. Block 1 is by far the largest, accounting for approximately two-thirds of the age-adjusted village population; blocks 2 and 4 each have slightly over 13% of the population.

The data in Table 1 suggest that few members of the groups with the lowest levels of rice income could survive on this income alone. From Bailey's account, it appears that the slack is taken up by wage labor, by crafts, by salary (as in the case of schoolteachers), or by trading, in which members of most groups in the village engage to some degree.

The block densities along the diagonal of Figure 4 are at or close to the mean for the matrix as a whole. This appears to highlight the widespread diversity and change in the society. At the same time, the picture of relative position that the model provides and its association of group with group, are striking.

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Permuted Matrix of Relations

1.	0	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
6.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	1
16.	0	1	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
17.	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	1
20.	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
2.	0	1	1	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
3.	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4.	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
5.	0	1	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
10.	0	1	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
12.	0	1	1	1	1	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1
13.	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
7.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
19.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0
21.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	1
11.	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	1
14.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1
15.	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1
18.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0

Block Densities

0.5	0.11	1	0.84
0.83	0.48	1	1
0	0	0.35	0
0.16	0	1	0.5

$\bar{x} = 0.49$

Image Matrix

0	0	1	1
1	0	1	1
0	0	0	0
0	0	1	1

Figure 4.
Block-model of relative intergroup domination in per capita rice income

Some of the groups included in the same blocks seem surprisingly different from their fellows, nevertheless; compare the average annual paddy income of groups 1 and 6, for example. In their exposition of block-modelling, White and his colleagues (1976: 731, 739) emphasize the technique's importance for revealing structural equivalence. By this term they mean the potential for one person or group to act in the same overall manner as another. They emphasize that the block-model algorithm focuses on the null cells of the matrix, searching for the best ways to construct zero or near-zero blocks; it does not try to construct blocks containing the maximum number of ones. What this means for a model such as that constructed here is that a group with comparatively few relations can be considered sociologically similar to

several other groups. And it can be assigned with them to the same block in the model if its limited relations go in the same directions as those of the more widely connected block members. This is exemplified in Figure 4. An empirical test of the validity of such assignment is possible: one can gather and analyze data to show whether groups or individuals placed in the same block actually follow similar social strategies. One can also examine whether groups with low economic status, who are attempting to rise, follow adaptations of the strategies used by those ahead of them in the same block, or the strategies used by those in other blocks.

Defining Economic Change and Cultural Continuity

At this stage we can recall some of the points made earlier about the nature of cultural principles and cultural continuity. In these earlier paragraphs, we suggested that cultural principles can be built on the basis of economic patterns and that these principles can be applied to the organization of society in spheres other than economics. The crux of the matter, of course, lies in identifying these patterns and their substantive nature. We can begin by comparing the density matrices, and their images, for three types of relation in Figure 5. The relations examined are those of dominance on the three measures in Table 1, and the permutation used is that in Figure 3.

Figure 5 provides us with information to define a regular system of relations based on economic activities in the society. Specific relations for consideration include the following:

- The most reduced images, those in the right-hand column of Figure 5, show a basic pattern of two groups with one dominating. By both measures of income, the agricultural majority (blocks 1 and 2) dominates a partially agricultural minority (blocks 3 and 4).

- Within the majority itself there are significant economic differences. These are seen in the first and second sets of images. The differences appear to be due to land ownership by members of block 1 and to relatively intensive involvement in trade on the part of the members of block 2.

- The four-block, squared images suggest that block 1 can extend its domination further through land ownership, while block 2 has the advantage through trade.

- For all three measures, block 4 occupies an interesting, intermediate position. There may well be material for important, political dynamics here: block 4 is in positions that would make the alliance of its members valuable for the members of either block 1 or 2.

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Density of Relations				Image	Image Squared	Reduction of Squared Image
Land Income						
0.5	0.8	1	1	0 1 1 1	0 0 1 1	
0.2	0.48	1	0.91	0 0 1 1	0 0 1 0	0 1
0	0	0.35	0	0 0 0 0	0 0 0 0	0 0
0	0.03	1	0.45	0 0 1 0	0 0 0 0	
1.5 $\bar{x}$ = .73						
Paddy Income						
0.5	0.11	1	0.84	0 0 1 1	0 0 1 0	
0.83	0.48	1	1	1 0 1 1	0 0 1 1	0 1
0	0	0.35	0	0 0 0 0	0 0 0 0	0 0
0.16	0	1	0.5	0 0 1 0	0 0 0 0	
1.5 $\bar{x}$ = .73						
Population						
0.5	0.94	1	0.92	0 1 1 1	0 1 1 0	
0.06	0.4	0.54	0.2	0 0 0 0	0 0 0 0	1 1
0	0.29	0.45	0.12	0 0 0 0	0 0 0 0	0 0
0.08	0.71	0.8	0.5	0 1 1 0	0 0 0 0	
1.5 $\bar{x}$ = .73						

Cutoff for initial image matrices is at 1.5x.
Reckoning for operations on the image matrices is binary: 1 + 1 = 1.

Figure 5. Density matrices and images for three types of relations

The relatively marginal status of block 3 is clear throughout.

Thus we may define economic culture for this society. The first point is simple: one section of the society dominates another in returns from the basic economic activity in the village. Cultural continuity at the most general level, therefore, consists of individual villagers expecting this pattern, consciously or unconsciously, and in their acting to deal with its consequences. Change would consist of the development of additional or alternative income sources, in which the substantive relationships of daily life and experience do not lead to the establishment of such stratification or to its expectation.

Note that the pattern itself is the primary cultural phenomenon under discussion here, and that this is so despite the fact that it can continue to exist, as a pattern, only on the basis of economic reality. The fact that one or another of the household clusters in the village occupies a dominant or

subordinate position is a matter of circumstance; depending on economic fortune, such groups can move in or out of a position without altering the basic cultural pattern itself. A particular group's association with a position may be long-lived and may itself come to be instituted and expected. Such association is cultural, but it is contingent, and it implies no necessary connection with the nature or continuity of the basic pattern. In addition, we should note that in order for a cultural pattern, such as the one we are discussing here, to be enacted in the relations developed by two or more individuals, it is not necessary for these individuals to belong to groups that occupy particular positions. Cultural expectation of inequality can lead two poor individuals or two rich persons to adopt strategies and choices that assume and lead to an unequal outcome between themselves.

Blocking only a single set of ties would have left us at this most general level. The availability of two separate measures of economic status, however, allows us to see more. Thus we can make statements about culture at a more detailed level, where determinants and mechanisms of strategy begin to come into play. We see that the two basic economic measures imply different sources of power and correspondingly different strategies for blocks 1 and 2. Thus we infer an additional principle of economic culture in this village: factionalism within the dominant stratum. We also see the potentially strong political role of block 4 and the essentially marginal status of some members of the society as far as paddy income and riceland income are concerned. It is likely that these patterns as well have become part of the cultural expectations of this village and that they have furnished material for the villagers' cultural manipulations.

We can expect that relations of employment, consultation, and so on are linked with these overall patterns. Following the discussion in the first part of the paper, we expect individuals to establish their personal, economic, and social relationships with an eye to the parts of the overall structure that affect (or which they expect will affect) them. In order to act successfully, however, it is not necessary to know everything about the positions of all fellow villagers. The basic patterns themselves provide individuals with overall, cultural interpretations for their situation, and the continuation or change of these patterns depends upon the continuation or change of overall, practical economic conditions. In a particular case, therefore, it is enough that actors are able to identify other individuals, or groups, who act on them or whom they can reach through their own networks. The individual actor then manipulates these connections, according to cultural understanding and according to the requirements of his or her personal situation, in an attempt to be sure that the individually desired results occur.

Apparently similar relationships, such as those of friendship or of employment, may be interpreted differently by different persons, depending upon

their own position in the structure. In many cases, ostensibly equal and reciprocal relationships will bear the potential for conflict because the actors' different positions lead them to value and to interpret the links differently. At the same time, there is cultural unity: both conflict and agreement can result from operation within the same framework.

The pattern abstracted for this village is based on a particular set of substantive, economic facts. By definition, strict agreement with the past requires continuation of the economic activities and the overall economic relations as we have described them. A new marketing endeavor or a new crop might be introduced; this would change the set of substantive facts and would open the possibility for development of a new cultural pattern. Existing power relationships can be strong, however, as can other individual and group social investments in ties. If the influences of power and of social investment are strong enough, new relations built on new sets of substantive facts would still follow the old pattern; thus, the structural form of the old culture would be preserved and would be applied to the regulation and manipulation of the elements of a new task. This kind of social structural and abstract continuity can occur even where such factors as power and its motivations are not immediately involved. Insofar as people act with the expectation that their existing patterns and rules for social interaction will continue to be useful, then their conduct, by itself, will exert pressure for continuity. Culturally fundamental change occurs when a new organizational structure grows up around an old or a new set of activities. In all cases, whether there is continuity or change, the structural pattern may require the development of compensating relationships to relieve or balance inherent conflicts.

Applying and Extending the Techniques

In the case at hand, we may be reasonably sure that the correct set of relationships has been used to construct the basic model. Bailey's (1957) description of the economy of Bisipara suggests this, and the model obtained looks familiar in terms of South Asian situations. Authors such as Karve (1968) discuss the maintenance of continuity in a village such as that modelled here. Srinivas' (1962) discussion of change, and of the ways social position influences group dynamics and the choice of roles and role models, rings true in terms of the block-model and in terms of Bailey's account.

In a different case, however, it might not be so clear which set of ties to model, and a certain amount of experimentation would be needed. It would be necessary to test alternative matrices, of alternative economic relationships, to see whether they help our understanding of the society and whether they assist us in unraveling the implicit rules in the networks people construct to meet their individual goals. Particularly in the case of a relatively

unknown situation, it should turn out that there is benefit not only in testing several sets of ties, but in examining several stackings of ties. As already noted above, data on mutually exclusive sets of ties can be particularly useful when they are available.

Supplementary techniques such as ranking (Siegel 1956) or scaling (Kerlinger 1986) may be required to gather data systematically on people's perceptions about ties, particularly about the relative importance of certain ties overall and their comparative efficacy in different situations. Perceptions are not everything, however: they are limited, and a significant portion of their meaning may be determined by position in the social structure. The techniques of matrix manipulation discussed here provide us with means for analytic testing, comparison, and discovery to draw extra meaning from ethnographic inquiry.

With such clues we can proceed to further questions. Do respondents identify one set of social relationships as primary, and another as secondary or complementary? If the notions of primary and secondary are useful, does their block-by-block identification differ nevertheless? Which relations are likely to be starting points and which endpoints in a series of strategic links? Which relations and which strategies of linkage are seen by members of the society to produce a peaceful, smoothly functioning state of affairs? What is the nature of the relationships or systems of relationships that help to equilibrate: to restore or to establish political and economic balance? What development interventions would reinforce the dynamic and productive forces within the social system? What if a new crop were introduced, or if marketing were improved for a presently low-value, low-emphasis crop?

The literature backing the methods applied here is extensive, and it continues to grow in both size and sophistication, yet its basics depend largely on a few concepts and techniques. The fundamentals of matrix manipulation are laid out in Hadley (1961) and by Kemeny et al. (1966). Leinhardt (1977) stands as a useful complement to the material in Kemeny et al., drawing together a number of strands in sociology and anthropology. Graph theory has contributed to a formal understanding of the connections and shortest paths among individuals, as well as to an understanding of balance in the systems which individuals build. Harary's (1959) article reprinted in Leinhardt's (1977) volume is a particularly useful introduction. Several basic pieces for further reading are cited by Harary, including pieces by Festinger (1949) and by Harary and Ross (1955) on the use of matrix algebra for the analysis of social connections.

Several sources exist which provide expansions or additional views of the methods set out in White et al. (1976) and in Boorman and White (1976). Arabie et al. (1978) provide a complete discussion of the methodology and

the mathematics of block-modelling. Arabie and his coauthors go into some detail on the genealogy both of block-modelling and of related procedures; their article is also useful for its extensive bibliography. Breiger et al. (1975) discuss the block-model algorithm. As White and his colleagues point out, block-modelling emphasizes groups and their interaction, instead of what has often been a narrower graph theoretic concern with individuals and shortest paths. The articles in Holland and Leinhardt (1979) develop analytic methods suited to this focus, relying in many cases on the methods and ideas of abstract algebra (Pinter 1982).

Conclusion

The methods discussed here allow for joint analysis of economic phenomena and the culturally sanctioned, social relationships that mediate economics and give it impetus. The methods are formal, yet flexible enough to take account of very small numbers of links among individuals if necessary. The questions the methods are suited to asking, and the phenomena they allow us to follow and to detail, are those forming major foci of analysis in contemporary work on institutional economics (Ben-Porath 1980; Evenson and Roumasset 1986).

The methods are suited not only to analysis of results (relative income, land ownership), but also to the recording and analysis of process. It is a simple matter, using matrix techniques, to describe the order and interaction among relationships (employment, consultation, exchange of assistance) established or evoked by a farmer in the course of growing a particular crop in a particular season, or in the course of constructing a capital improvement such as a well. If the question is one of a particular, planned intervention, whether this involves new varieties or fertilizer or marketing or irrigation, it is possible to define both the preexisting situation and the desired changes in terms of relational systems such as those examined here.

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STRATEGIC PLANNING— CONCEPTS AND ISSUES

Selcuk Ozgediz

Abstract

This paper focuses on conceptual and process issues related to strategic planning in international agricultural research organizations. A strategy outlines where the organizations is headed, what course it plans to follow to get there, and why the chosen course is the best. An integrated planning, evaluation, and control framework consists of (1) strategic concerns — any system needs a process and criteria for arriving at a system strategy; (2) operational concerns — a medium-term plan is needed, including a program and budget; and (3) monitoring, evaluation, and control concerns — thorough impact assessment and input monitoring is needed for progress of the system. This framework can be applied at three levels: (1) multi-institute activities, (2) institute activities, and (3) program activities. One of the most important challenges facing research institutions is to find ways of encouraging strategic thinking at all levels of the organization. For organizations that have not gone through the experience, strategic planning helps initiate and motivate strategic thinking.

Introduction

Mission-oriented, nonprofit research organizations such as the international agricultural research centers supported by the Consultative Group for International Agricultural Research (CGIAR) are finding themselves under increasing pressure to justify their continuing existence. This pressure stems, in part, from the increasing scarcity of and competing demands for donor funds for research and related activities. Moreover, the uncertainty of high returns to investments in specific long-term research projects also reinforces the pressure to have a clear rationale for engaging in different

research activities. Many such organizations have turned to long-term strategic planning as a means of analyzing their response to these pressures.

Strategic planning (SP) among the CGIAR centers has gained momentum since 1986 as a result of three mutually reinforcing developments. First, CGIAR approval of the recommendations of a system-level strategy and priority paper prepared by its Technical Advisory Committee (TAC) in 1986 served as an impetus to the centers to align or rethink their programs in terms of the newly stated CGIAR goal and objectives. Second, the system-wide move from an annual towards a medium-term resource-allocation system increased the demands on the centers for preparing clear strategic statements as the underlying rationale for their medium-term program and budget proposals. Third, a consensus began to build within the system on the need to focus the external reviews of the centers more towards long-term strategic concerns, as compared with short-term operational matters. This placed added pressure on the centers to prepare or update their strategic plans before the external reviews.

This paper attempts to throw some light on conceptual and process issues related to strategic planning. Although its main focus is on strategic planning in international agricultural research organizations, many of the concepts and generalizations are equally applicable to other nonprofit institutions.

The Concept of Strategy

There is some confusion in the management literature about the precise definition of strategy. Let me illustrate with a few examples.

Von Neumann and Morgenstern (1944) were among the earliest users of the term *strategy* in its modern sense. In their classic study on decision theory, they define *strategy* as a plan, prepared before the start of a game, which specifies the choices a player could make in every possible situation, under all possible scenarios on the amount of information available to him (Von Neumann and Morgenstern 1944: 79). Thus, strategy is seen as a guide to action, prepared after careful consideration of possible moves by other actors and the likely outcomes from these moves.

Another classic definition is the one by Chandler (1962: 13): "Strategy can be defined as the determination of the basic long-term goals of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals." Here the emphasis is on defining where the organization should be headed and identifying the avenues by which can get it there.

The definition by Tilles 1963: 84) also underlines goals: "A strategy is a set of goals and major policies." By goals, Tilles refers to what an organization is aspiring to achieve as well as what it, in its totality, wishes to become in the long term. Major policies, on the other hand, refer to key decision rules that can guide the making of specific choices.

While the three definitions quoted above have a futuristic, planning orientation, the one offered by Mintzberg and Waters (1985: 257) is less temporal: "patterns in streams of (organizational) actions." Thus, according to these authors, what counts in understanding an organization's strategy are actions, some of which may be planned or intended, but others can emerge in an unplanned manner. The organization's strategies can be detected only by a search for consistent patterns in actions.

There are several threads common to these definitions. First, directly or indirectly they have an action orientation (more in the form of a guide to action than specific action steps). Second, they place a great deal of emphasis on the spelling out of a course, a direction, or a consistent pattern of action for the organization. Third, several of the definitions view long-term goals or visions as part of the organization's strategy.

The definition of strategy I use shares many of these features:

> An organization's strategy describes the most desirable vision of its future, outlines the essential elements of a course it intends to follow to realize that vision, and provides a justification for the identified course.

Several aspects of this definition need comment. First, a strategy typically illustrates a course that an organization believes should be followed. One can also have a strategy not tied to an organization — such as an agricultural research strategy for sub-Saharan Africa drawn up by a multilateral agency — but this serves mainly as a *suggestion* to the institutions directly involved because it does not take into account their specific circumstances.

Second, the vision of the organization's future that is summarized by the strategy shows where the organization wants to be in the future. It typically reflects the visions of the leader(s) of the organization (that is, the person(s) accountable for its overall performance) about the kind of institution it should become. Much of strategic planning deals with analysis of the organization's likely future environment, to help the guiding members of the organization determine where the institution should be headed.

Third, the course the organization intends to follow reflects the broad choices made in order to transform it from its present state to its desired future

state. In day-to-day usage, the term *strategy* often refers only to the course or direction chosen by the organization.

Fourth, justification of the identified course is necessary in order to clarify the rationale behind the chosen strategy. This is particularly important for nonprofit institutions which need to communicate their strategy to a wide range of stakeholders.

To summarize, a strategy outlines where the organization is headed, what course it plans to follow to get there, and why the chosen course is the best.

Levels of Strategy

In the literature on corporate planning, a distinction is often made between enterprise (institutional), corporate, and business strategy. Enterprise strategy refers basically to what the company as an institution stands for (Freeman 1984). Corporate strategy concerns the determination of the businesses the company should be in and the allocation of resources to these businesses. Business strategy addresses questions of direction and competitive positioning (Hamermesh 1986).

The hierarchy of strategies noted above can be carried further to the sub-business, product, or unit level. However, as one moves further down the hierarchy, the range of strategic choices available becomes narrower and narrower.

All three major levels of strategy mentioned above (enterprise, corporate, and business) are relevant to autonomous research organizations, even if they are not part of a larger corporation like IBM or General Electric. There is a need to answer enterprise-level questions such as "what is our basic character as an organization," "what is our place in the world," and "what values do we subscribe to?" Corporate-level questions such as "what businesses should we be in" and "how should we allocate our resources to our businesses" also need answers. Once these higher-order questions are answered, there is a further need to find answers to more specific questions for each business the research organization is engaged in, such as "where should we be headed in this business" and "what policies or courses of action should we adopt to succeed?"

Our definition of strategy encompasses all three levels of strategy. The vision of the organization's future relates mainly to enterprise- and corporate-level questions. The course to be followed by the organization, on the other hand, covers questions of resource allocation at the corporate level and the specific direction to be pursued in each business. Our stress on the need for spelling out the rationale for the chosen strategy applies to all three levels.

Components of Strategy

A well-articulated strategy summarizes two types of information. First, it provides contextual information of relevance to the future of the organization, including analysis of its implications. Second, it outlines the basic strategic choices made by the organization at the enterprise, corporate, and business levels, along with their rationale. In what I list below as major components of strategy, some of the items relate mainly to information, some to aspects of strategy, and some to both. Although it could be argued that the information items should not be considered part of the strategy, the rationale for the strategy becomes clearer if these are included.

Clients and Beneficiaries

A strategy should clearly identify the direct clients of the organization, i.e., those who would be benefitting directly from the products or services generated by the organization. It should also identify the clients of the organization's clients (or the indirect beneficiaries). In the case of the international agricultural research organizations, the former typically includes national agricultural research systems and the latter includes population groups such as poor farmers and women.

Merely listing future clients and beneficiaries by type and location is not sufficient. What is important is to determine the characteristics or aspects of the clients the organization would wish to influence or change through its own activities (such as the scientific research capabilities of national agricultural research systems). Knowledge of the needs of the clients' clients often helps better define the needs of the organization's clients. For international agricultural research institutions, the strategy should reflect a good understanding of the factors contributing to the effectiveness of national agricultural research systems so that, through its future activities, the international center can zero in on those factors that can provide the greatest leverage.

External Environment

A strategy should describe a vision of the organization as it is seen to operate in the future. Development of this vision requires having an understanding of the organization's likely future external environment and the opportunities and threats likely to be presented by this environment.

Several aspects of the external environment are important. First, it is important to have a clear understanding of the interests of the organization's major external stakeholders so that the strategy is formulated with stakeholders' views taken into account. A stakeholder is "any group or individual

who can affect or is affected by the achievement of the organization's objectives" (Freeman 1984: 46). (The clients of the organization also constitute a stakeholder group, but because of their importance I cover them separately, above). In the case of the international agricultural research centers, stakeholder analysis should cover, at the minimum, groups such as major donors, the CGIAR and TAC, other international centers with competing or complementary mandates, and the governmental and nongovernmental institutions in the major countries in which the center operates.

Second, it is important to understand world or specific market trends in areas of interest to the organization. For agricultural research institutions, these include matters relating to the organization's beneficiaries (population, nutrition, other socioeconomic trends), the physical environment (such as increasing concern over environmental sustainability), the institutional environment (such as increasing use of organizational forms like networking), the technological environment (such as trends in information technology), and the scientific environment (such as trends in basic research or research methodology).

Internal Environment

An understanding of the organization's internal environment is necessary in order to formulate a strategy that builds on institutional strengths and overcomes weaknesses. Several aspects of the institution's internal environment are important. First, the interests of internal stakeholders (such as managers, staff, and the members of the governing body) are important. Second, the culture of the organization (commonly defined as shared patterns of values, beliefs, norms, and behaviors in an organization) needs to be understood. Third, the organization's past achievements and important competencies and limitations need to be described and analyzed.

Current Strategy

An organization's future strategy should make reference to its current strategy and provide a rationale for changes, if any. The current strategy, or "strategy-in-use," can be described essentially in the same way as the future strategy. An organization's strategy-in-use can be deduced from its past actions (Mintzberg and Waters 1985), regardless of whether the organization has followed a written strategic plan. What is important, though, is a critical assessment of the current strategy.

According to Tilles (1963), the following criteria can be used in assessing current strategy: evidence of impact; internal consistency with values and culture, competencies and resources, and organizational structure; external consistency with client needs, stakeholder interests, and other important

aspects of the organization's environment; and appropriateness of the time horizon of the strategy.

Mission

A strategy needs to state clearly the mission of the organization, that is, why it exists and what goals it should pursue. This would reflect the vision of the organization's leadership about where the institution should be headed in the future.

The organization's formal or constitutional mandate often defines the constraints and parameters within which the institution should operate. The mission spelled out in the strategy, on the other hand, serves as the operational mandate for the period under consideration. Conflicts between the formal mandate and the mission need to be resolved by introducing changes in one or the other.

The term "mission statement" is used frequently in the literature on strategic planning to refer to the mission as defined above, plus a synopsis of the major aspects of the organization's strategy (Pfeiffer et al. 1985). Having a short statement that summarizes the chosen strategy is very helpful in communicating the strategy to the staff and the stakeholders.

Guiding Values

A strategy clarifies and reinforces the values the institution stands for. Guiding values reflect the business philosophy of the organization and illustrate the broad principles the institution subscribes to. They serve as a guide to operations and can be used as criteria in making strategic choices.

Incongruities between the present culture of the organization (which is being studied by CIMMYT as part of its strategic planning effort) and the guiding values selected for the future requires taking measures for culture change. This is one of the least understood aspects of organizational change, and one for which there are no "cookbook" solutions (Kilmann et al. 1985; Tichy 1983; Deal and Kennedy 1982).

Guiding values typically cover areas such as how the organization relates to its clients (that is, how it views its role vis-a-vis its clients), other external stakeholders, and its staff (which reflects how much the staff are valued by the organization). Other possible areas for guiding values include the organization's philosophy regarding the characteristics of the product or service provided (such as quality of service) and its views on risk taking and use of resources. The actual contents of what might be called a "value map" for an organization depends on the specific circumstances of that organization.

Business Areas

I use the term "business" in the corporate planning sense, i.e., referring to the major strategic areas the organization wishes to work in. These are normally specified in the formal mandate and the mission statement.

The criteria for defining business areas relate mainly to aspects of the organization's environment, not its internal structure. Categories of clients or their needs, geography, or type of product/service are commonly used as criteria (Hanna 1985). Most international agricultural research centers have two major businesses: research and strengthening national agricultural research systems (NARS). The former can be partitioned into smaller businesses such as "germplasm development" and "crop management" and the latter into "improving research capabilities of NARS" and "meeting the information needs of NARS." These need not correspond to the organization's existing departments or units.

This partitioning into smaller businesses is necessary because the organization may wish to follow a distinctly different course in each business. Strategic issues relevant to the institution's training "business," for example, would be different from those relating to its germplasm-development activities.

A strategy identifies both the business areas the organization should work in and also the goals to be pursued and the direction to be followed in each business. Business-area goals should be derived from and substantively linked with the organization's overall mission. That is, the rationale for each business and its goal must be made explicit.

Strategic Issues

These are fundamental policy questions about directional choices the organization needs to make. A strategic issue often reflects a current or forthcoming development, inside or outside the organization, which has an important bearing on what the organization should do or how it should do it. Strategic issues often relate to the major strengths and weaknesses of the organization and the threats and opportunities it faces (Ansoff 1980; Bryson 1987).

Analysis of strategic issues represents the "guts" of a strategy as they throw light on the courses to be followed by the organization in accomplishing its overall mission and business-area goals. Analysis of the needs of clients and beneficiaries, assessment of the internal and external environment, and evaluation of the current strategy all lead to identification of the major issues to be addressed by the strategy.

Examples of strategic issues currently confronting international agricultural research institutions include the balance between basic and applied research, ways of addressing sustainability concerns, modes of collaboration with NARS, general versus specialized training, centralization versus decentralization of activities, and ways of financing the implementation of the strategy.

Priorities

Priorities are part of an organization's strategy. A strategy needs to reflect corporate-level strategic choices, i.e., the relative priorities assigned to major business areas and subareas. This is often expressed in terms of a planned flow of financial or manpower resources (or both) to business areas over time. The rationale for the chosen pattern of resource allocation also needs to be spelled out in the strategy or its supporting documents.

Operational Implications

A strategy represents a scenario for organizational change, i.e., moving the organization from its present state to a desired future state (Egan *forthcoming*). There is no universal rule that can be used to differentiate strategic from operational concerns. Strategies cannot be formulated without taking into account implementation considerations, and some degree of overlap between the two plans (strategic and operational) is both unavoidable and desirable. A scenario for change that focuses only on the business aspects of the organization would be incomplete without reference to the implications of the strategy for other institutional changes, such as in the organizational structure, staffing mix, and physical infrastructure. A strategy should draw only the broad outlines of the changes planned in these areas.

The key stakeholders of research organizations are often as much interested in the broad strategic directions of the institution as they are in the approaches proposed for solving specific research problems. Some of these are project- and program-level "tactic" questions one would ordinarily not include in a strategy. However, if one of the purposes of formulating a strategy is to communicate the organization's thinking about its future to its stakeholders, it is necessary to broaden the scope of the strategy to include some key operational matters.

Components of Strategy — Ten Key Questions

1. Who are our potential future clients and which of their needs can we meet?

2. What are the implications of our likely future external environment on where we should be headed and what we should do in the future?

3. What are the implications of the strengths and weaknesses of our internal environment for our future work?

4. How effective is our current strategy?

5. Where should we be headed in the future; what should be our mission?

6. What should be our guiding values and business philosophy?

7. What businesses should we be in and what goals should be pursued in each business?

8. What are the major strategic issues we are confronted with and directional choices we need to make?

9. What priorities should we assign to our business areas and subareas as we move towards the future?

10. What are the major operational implications of our future strategy, particularly in terms of financing, staffing, physical infrastructure, and organizational structure?

Strategic Planning

Strategic planning is a response to the inadequacies of the planning systems used in the 1950s and '60s. Financial planning approaches, such as the planning, programming, and budgeting system (PPBS) and zero-based budgeting, placed heavy emphasis on short-term efficiency at the expense of the long-term positioning of the organization. Traditional long-range planning, on the other hand, has relied on forecasting based on past trends, often leading to formulation of detailed multiyear blueprint plans which quickly became obsolete (Hanna 1985; Porter 1987).

The origins of strategic planning lie in the private sector of the United States. Its conceptual foundations go back to the work of the Harvard Business School in the 1950s to develop the best "fit" between an organization and its environment. One of the first major applications of strategic planning was the pioneering work in General Electric Corporation in the 1960s on ways of deciding how corporate resources should be allocated to different strategic business units (Hamermesh 1986). Since then several approaches have emerged under such titles as strategic planning systems, stakeholder management, strategic issue management, portfolio analysis, and competitive

analysis. The use of strategic planning in the public and private nonprofit sectors, however, has been limited (Bryson and Roering 1987).

The definition of strategic planning follows from the definition of strategy given above. Accordingly, strategic planning refers to a process by which an organization develops the most desirable vision of its future, outlines the essential elements of a course it intends to follow to realize that vision, and provides a justification for the course identified. Regardless of how it is prepared, a strategic plan should include the basic components of strategy described above.

From a management standpoint, strategic planning is one link in an integrated institutional planning process. The strategic plan provides an essential overall framework for guiding the organization, but it is several steps away from action. The courses and directions laid out in the strategy need to be operationalized to set the stage for their implementation. This is usually referred to as operational or program planning. Finally, the implementation of both the strategic and the operational plan need to be monitored in order to learn from experience, to incorporate new developments, and to confirm the continuing appropriateness of the strategy.

Figure 1 illustrates the integrated planning process described above. The process is integrated in the sense that each component influences every other component. The strategic plan, which provides the starting point for the process, takes into account operational considerations, even in the absence of an operational plan. The operational plan follows from the strategy. The monitoring and control systems, on the other hand, help assess results and contribute to reformulation of strategic and operational plans (Below et al. 1987; Morrisey et al. 1988).

The operational plan covers a shorter duration than the strategic plan. In the private sector, strategic plans usually have a perspective of about five years and operational plans are prepared annually. Most of the centers within the CGIAR prepare strategic plans with a 10- to 15-year perspective. Two kinds of operational plans for centers are prepared in the CGIAR: a medium-term program covering a five-year period and an annual program budget.

The focus of an operational plan is on action plans and budgets. It translates the business-area goals and strategies contained in the strategic plan into programs and projects with shorter-term objectives. Monitoring and control systems, on the other hand, are designed to generate the information needed to assess performance at the institution, program, unit, and individual levels. In addition, they help assess the implications for the organization of trends and developments in the external environment.

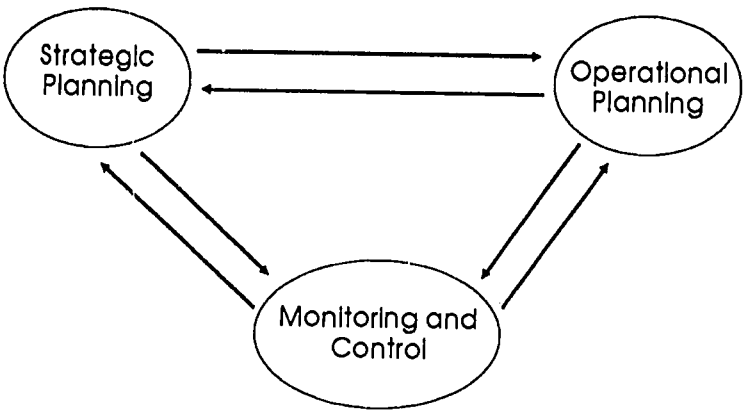

Figure 1. Integrated planning process

A Strategic Planning Process Model

In the final analysis, what matters for an organization is the content of the strategy, not the process used to formulate it. On the other hand, the process used is also important as it can serve purposes other than producing a plan. Also, one process may be more efficient than another. Because strategic planning is as much a crafting exercise as it is straightforward planning (Mintzberg 1987), no single process is likely to suit the needs of all organizations.

There are several useful process models that may be suitable to research organizations. A model by Below et al. (1987), for example, places strategic planning in the context of an integrated planning framework and provides detailed procedures for formulating a strategic plan. Another process model provides useful guidelines and practical advice to managers (Pfeiffer et al. 1985). A third, developed specifically for public and nonprofit organizations, has much to offer to research organizations (Bryson 1987).

The model I advocate, illustrated in Figure 2, captures the main arguments made in this paper. The process can be summarized as follows:

Planning to Plan (Box 1 in Figure 2)

I have singled this out as a separate task because of its importance. All the organizations I have worked with on strategic planning have found it useful to establish a strategic planning team (SPT) from within the organization. The SPT usually includes the top management team plus other key staff. The group should preferably be led by the chief executive officer. The size of the group can vary, but inefficiencies begin creeping in when it exceeds 12.

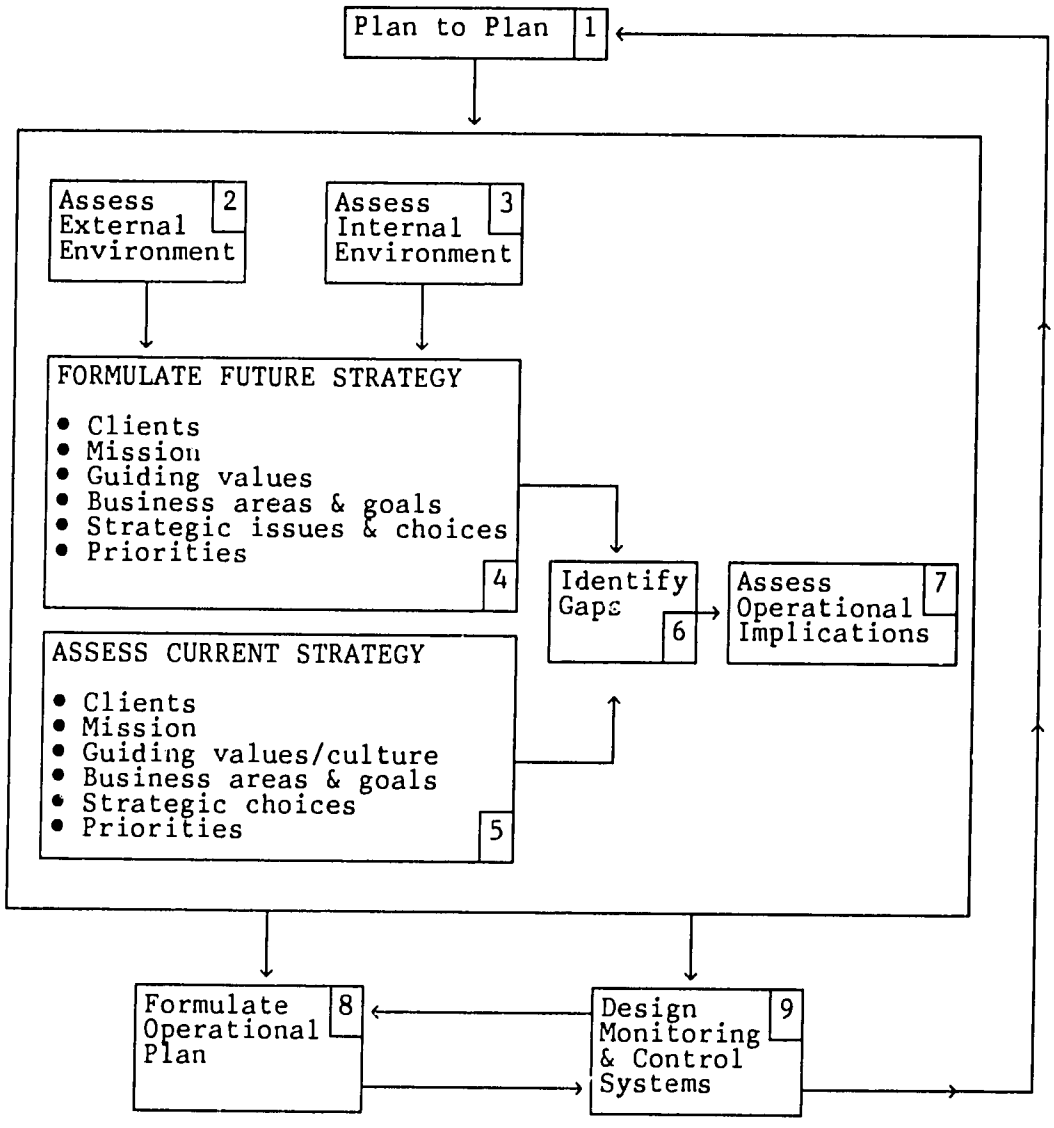

Figure 2. A strategic planning process model

It is useful for the SPT to go through a two- to three-day seminar and brainstorming session on strategic planning with the help of an external consultant. This session should aim at sensitizing the group to the concepts, rationale, and processes of strategic planning as well as establishing a common framework and a communication base. The key tangible output of this task is an organizational framework (including subcommittees and task forces) and an action plan for formulating the strategic plan. An important

intangible output is the commitment of the members of the SPT to strategic planning and the roles they will play in implementing the action plan.

Formulating Future Strategy (Boxes 2-4)

I favor an iterative, zero-based approach to strategy formulation, where in the first iteration, the future strategy is formulated without reference to the current strategy. This increases the chances for the plan to be more future-driven than otherwise.

It is also useful for the SPT to consult widely with external groups, such as representatives of the clients, in the formulation of future strategy. Another is a group of outside experts who are knowledgeable about likely future developments in the businesses of interest to the organization and on the strategic issues that should be analyzed. Internal consultation with the staff not involved with the planning is also essential, in spite of the fact that this often increases the pressures for maintaining the status quo.

Assessing Current Strategy (Box 5)

This is particularly important for organizations with no written strategy or a monitoring/control system for assessing the implementation of the strategy. It is helpful to assess the current strategy in terms of the same components as in the future strategy.

Identify Gaps (Box 6)

Analysis of the differences between the current strategy and the first formulation of the future strategy helps identify major strategic changes, so that their organizational and operational implications can be studied.

Assessing Operational Implications (Box 7)

The SPT should study the major strategic changes identified in terms of their implications for financing, staffing, physical facilities, organizational structure, and culture change. These findings often lead to a reconsideration of the future strategy.

Formulating the Operational Plan and Designing the Monitoring and Control Systems (Boxes 8 and 9)

These represent the other two components of the integrated planning process described above and are shown in Figure 2 to illustrate their links with strategic planning. It should be reemphasized that the monitoring and control system needs to address operational as well as strategic concerns.

This would make the strategy a "living" document and alert the organization early on when there is need to reconsider the strategy-in-use.

Concluding Observations

One of the most important challenges facing research institutions is to find ways of encouraging strategic thinking at all levels of the organization. For organizations that have not gone through the experience, strategic planning helps initiate and motivate strategic thinking. This initial impetus should be reinforced and sustained by encouragement of continuous strategic analysis throughout the organization. Supporting the preparation of unit strategic plans can help instill organization-wide strategic thinking.

Formulating a strategic plan is costly; therefore, extreme caution should be exercised in choosing a planning process in order to avoid overplanning. Most decision makers are interested only in the main lines of an organization's strategy. Lengthy strategic planning documents often confuse the readers and could do more harm than good to the organization.

One of the purposes of strategic planning is to clarify and simplify why an organization exists and what would make it successful. This does not require creating a large planning bureaucracy or preparing thick planning manuals. The guiding members of an organization, i.e., those responsible for developing visions of its future, should be seen as its key strategic planners.

CIMMYT and several other international agricultural research institutions are currently engaged in formulating strategic and operational plans. In addition, CIMMYT intends to document the planning process it is using. Because the experiences of the centers is unique among nonprofit international organizations, stocktaking of the lessons learned will add to our current knowledge on planning.

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Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research

Volume II: Assessing the Impact of Agricultural Research

Proceedings of the ISNAR/Rutgers Agricultural Technology Management Workshop, 6-8 July 1988, Rutgers University, New Jersey, USA

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The International Service for National Agricultural Research (ISNAR) began operating at its headquarters in The Hague, Netherlands, on September 1, 1980. It was established by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force, for the purpose of assisting governments of developing countries to strengthen their agricultural research. It is a non-profit autonomous agency, international in character, and non-political in management, staffing, and operations.

Of the thirteen centers in the CGIAR network, ISNAR is the only one that focuses primarily on national agricultural research issues. It provides advice to governments, upon request, on research policy, organization, and management issues, thus complementing the activities of other assistance agencies.

ISNAR has active advisory service, research, and training programs.

ISNAR is supported by a number of the members of CGIAR, an informal group of approximately 43 donors, including countries, development banks, international organizations, and foundations.

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Preface

The International Service for National Agricultural Research (ISNAR) and Rutgers (the State University of New Jersey) organized a workshop on the methods for assessing research impact and for diagnosing research systems constraints. This workshop was held in July 1988 at New Brunswick, New Jersey, USA. It was financed by USAID, IICA, ISNAR, Rutgers University, and the Rockefeller Foundation.

The purpose of the workshop was to provide a forum for discussing the methods of assessing the impact of research and diagnosing constraints on research systems with the goal of developing a consensus on the methodology for both assessment and diagnosis.

A call for papers for the workshop yielded over 50 submissions, of which 23 were chosen to be included. A peer panel of seven professionals — Ralph Cummings (AID), Howard Elliott (ISNAR), Robert Evenson (Yale University), Reed Hertford (Rutgers), Carl Pray (Rutgers), Margaret Sarles (Rutgers), and Eduardo Trigo (IICA) — selected the papers. These papers dealt with original research carried out by their authors. Most papers had neither been widely disseminated nor previously discussed.

Twenty-four authors participated in the workshop, including experts from donor organizations, international agricultural research centers, government agricultural agencies, and university programs in agriculture and economics. These individuals are recognized leaders in the development of the methodologies that were presented. In addition, representatives of NARS from Asia, Latin America, and Africa attended the workshop (sponsored by IICA, ISNAR, and AID) in order to provide feedback on the methodologies under discussion and to learn new analytic skills.

Dr. Reed Hertford, Director of the International Agricultural and Food Program (IAFP) at Rutgers University, was secretary for the workshop. IAFP Staff Members, Ms. Sue Randall, Ms. Marilyn Kluberspies, and Ms. Carrie Foushee, provided administrative support. Dr. Howard Elliott, Deputy Director General of Research and Training at ISNAR, co-hosted the workshop and provided logistic support. Both Dr. Hertford and Dr. Elliott guided the overall development of the workshop.

The workshop was organized around two groups, one that focused on diagnosing research systems constraints and the other on assessing the impact of agricultural research. Volume I of this report includes the papers on diagnosing systems constraints, and Volume II includes those on assessing the impact of agricultural research. Most of the papers included in this volume have been revised by their authors — at the editor's request — since being presented at the workshop in 1988. The editor thanks the authors for their contributions and Monique Hand and Kathleen Sheridan for their assistance in preparing this volume. All views expressed in this volume are the responsibility of the respective author(s).

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Assessing the Impact of Agricultural Research

Ruben G. Echeverría

Abstract

This paper presents a brief discussion of some of the issues related to assessing the impact of agricultural research and highlights the main points of the papers included in this volume. Many studies have estimated a high payoff to investments in research (and extension), focusing on a wide range of commodities, projects, programs, and also at an aggregate institute and national level. A table, presented in this paper and including more than 100 cases throughout the world, summarizes most of the published studies on returns to research since the late 1950s. Significant developments in the last two decades have enhanced the economic evaluation of the impact of agricultural research, both at the conceptual and methodological levels. The papers in this volume deal with general and specific (regional) cases of impact assessment. The general cases consider the challenges of assessing the impact of agricultural research, the measurement of producer and consumer surplus gains from quality improvement in crop varieties, the concept of excess burden associated with the use of tax funds to support research, and the question of omitting private-sector research when measuring the impact of public research. The regional cases focus on Latin America and include studies evaluating the impact of research at three different levels: a regional system (CARDI), a country (Peru), and specific commodities (pastures, cassava).

Introduction

This paper has two objectives: (1) to provide a brief overview on the issue of assessing the impacts of agricultural research and (2) to highlight the main points of the papers included in this volume.

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Many studies have shown a high payoff (rates of return above 50%) to investments in agricultural research on a wide range of commodities. They have also measured the impacts of research at different levels of aggregation: project, program, institute, region, and nation. Table 1 summarizes the results of these estimates.

Table 1 includes a diversity of studies from the pioneering work of Griliches in 1958 to more recent estimations of the benefits of agricultural research. With a few exceptions, these calculations yield significant results in all areas and levels of aggregation. Most of the studies conducted outside of the developed world have focused on Latin America and Asia, with only a few in Africa.

Several procedures have been developed to calculate benefits from research. For example, Schultz (1953) developed the "value of inputs saved" approach in the first study to quantify returns to investments in agricultural research.[1] Since then two primary methods have been used to calculate returns to research (and extension):

1. The economic-surplus approach (consumer-producer surplus, cost-benefit, and index number methods) estimates returns on investment (generally an average rate of return) by measuring the change in consumer and producer surplus from a shift to the right in the supply curve due to technological change.

2. The econometric approach (production, profit, and supply functions and their derivations) treats research as a variable and allows a marginal rate of return on investment to be calculated.

The economic-surplus approach measures the increase in the value of output caused by research from a given level of conventional inputs. The econometric approach includes lagged research expenditures as variables or inputs in a function. Production functions have been widely used for this purpose, as have profit and supply functions (and derivations). The main advantage of the economic-surplus approach is that it allows the distribution of benefits between producers and consumers to be calculated, while econometric methods offer a more rigorous analysis (statistically) of the impact of research on output. The return to investment in research can be expressed as an average rate (internal rate of return) for an entire project given specified expenditures or as a marginal rate that shows returns to the marginal unit of money invested.

[1] See Norton and Davis (1981) and Sumelius (1987) for a comprehensive review of the methods of estimating economic returns to research. See also Davis (1981) for a discussion of the conceptual relationship between the economic-surplus and the production-function approaches.

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Table 1. A Summary of Estimates of Returns from Investments in Agricultural Research (and Extension), 1958 to 1990

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Griliches	1958	USA	Hybrid corn Hybrid sorghum	(1940-55) (1940-57)	ES	35%-40% 20%
Tang	1963	Japan	Aggregate	(1880-1938)	EC	35%
Griliches	1964	USA	Aggregate	(1949-59)	EC	35%-40%
Latimer	1964	USA	Aggregate	(1949-59)	EC	not significant
Grossfield and Heath	1966	UK (NRDC)	Mechanical potato harvester	(1950-67)	ES	net contribution using simple cost-benefit analysis is UK £271,000
Peterson	1967	USA	Poultry	(1915-60)	EC	21%-25%
Evenson	1968	USA	Aggregate	(1949-59)	EC	47%
Evenson	1969	S. Africa	Sugarcane	(1945-62)	ES	40% — Same result using a production function for the period 1945-58.
Ayer	1970	Brazil (Sao Paulo)	Cotton	(1924-67)	ES	77%
Barletta	1970	Mexico	Crops wheat	(1943-63)	EC ES	45%-93% 90%
Schmitz and Seckler	1970	USA	Tomato harvester	(1958-69)	ES	16%-46%
Elías *(revised by Cordoml)*	1971 *1989*	Argentina (EEAT-Tucumán)	Sugarcane	(1943-63)	EC	33%-49% — includes extension.
Duncan	1972	Australia	Pasture improvement	(1948-69)	EC	58%-68%
Hines	1972	Peru	Maize	(1954-67)	ES	35%-40% and 50%-55% including cultivation.
Evenson and Jha	1973	India	Aggregate	(1953-71)	EC	40% — includes extension and the interaction between research and extension.

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Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Patrick and Kehrberg	1973	Brazil (Eastern)	Aggregate	(1968)	EC	Not significant estimate of returns to extension (number of contacts between farmers and extension agents).
Huffman	1974	USA (Corn belt)	Maize	(1959-64)	EC	Estimate of returns to extension yield a social return above 16%.
Cline	1975	USA	Aggregate	(1939-48)	EC	41%-50% — lower estimate for 13-year time lag and higher for 16-year lag between beginning and end of output impact.
del Rey (*revised by Cordomí*)	1975 *1989*	Argentina (EEAT-Tucumán)	Sugarcane	(1943-64)	EC	35%-41% — includes extension.
Mohan and Evenson	1975	India	Aggregate	(1959-71)	EC	Estimate of a social rate of return to extension is 15%-20%.
Monteiro	1975	Brazil	Cocoa	(1923-85)	ES	19%-20%
Peterson and Bredahl	1975	USA	Aggregate	(1937-42) (1947-57) (1957-62) (1967-72)	EC	50% 51% 49% 34%
Bredahl and Peterson	1976	USA	Cash grains Poultry Dairy Livestock	(1969)	EC	36% 37% 43% 47% Lagged marginal product of 1969 research on output discounted an estimated mean lag of 5 years for cash grains
Huffman	1976	USA (Iowa, N. Carolina, Oklahoma)	Crops and livestock	(1964)	EC	Estimate of returns to extension; marginal product of extension is $1,000 to $3,000 per day.
Fonseca	1976	Brazil	Coffee	(1933-95)	ES	23%-27% and 17%-22% when including extension.

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Easter and Norton	1977	USA	Maize		ES	Ex ante study of the land-grant university research & extension system
			Crop protection	(1982-2000)		Benefit-cost ratio of 137 : 1
			Production efficiency	(1985-2000)		Benefit-cost ratio of 118 : 1
			Soybeans		ES	Ex ante study of the land-grant university research & extension system
			Crop protection	(1982-2000)		benefit-cost ratio of 45 : 1
			Production efficiency	(1985-2000)		Benefit-cost ratio of 40 : 1
Eddleman	1977	USA	Aggregate	(1978-85)	ES	28 % An ex ante study to estimate expected economic benefits
			Maize			32% from federal funding for production-oriented research by state
			Soybeans			31% experiment stations
			Wheat			46%
			Beef cattle & forage			16%
			Swine			52%
			Dairy			38%
Halim	1977	Philippines (Laguna Province)	Aggregate	(1963-68-73)	EC	Estimate of returns to extension, positive and significant result.
Hayami and Akino	1977	Japan	Rice breeding	(1915-53)	ES	25%-27% — research programs before Assigned Exp. System
				(1932-61)		73%-75% — research programs under Assigned Exp. System. Both analyses consider autarky and open-economy cases.
Hertford et al.	1977	Colombia	Rice	(1957-80)	ES	60%-82%
			Soybeans	(1960-80)		79%-96%
			Wheat	(1927-76)		11%-12%
			Cotton	(1953-72)		0%
Huffman	1977	USA (Corn Belt)	Crops	(1959-64)	EC	Estimate of returns to extension yield a social rate of return of 110%.
Kahlon et al.	1977	India (Four states)	Aggregate	(1960-73)	EC	63%
				(1956-73)		14%-64% — States are A. Pradesh, Bihar, Maharastra, and Punjab.
Lu and Cline	1977	USA	Aggregate	(1938-72)	EC	24%-31%
Pee	1977	Malaysia	Rubber	(1932-73)	ES	24%

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Peterson and Fitzharris	1977	USA	Aggregate	(1937-72)	ES	34%-51% — considers four 6-year periods: 1937-42, 50%; 1947-52, 51%; 1957-62, 49%; and 1967-72, 34%. Includes extension and private R&D.
Wennergren and Whittaker	1977	Bolivia	Sheep Wheat	(1966-75)	ES	+ 44% to – 48%
Evenson	1978	USA	Aggregate	(1949-71)	EC	110% — estimate of returns to extension.
Evenson and Flores	1978	Asia (national) (intern'al)	Rice	(1950-65) (1966-75)	EC	32%-39% 73%-78% 74%-102%
Flores et al.	1978	Philippines	Rice	(1966-75)	EC	75% and 46%-71% for the tropics.
Kislev and Hoffman	1978	Israel	Wheat Dry farming Field crops	(1954-73)	ES	125%-150% 94%-113% 13%-16%
Lu, Quance, and Liu	1978	USA	Aggregate	(1939-72)	EC	25%
Mooch	1978	Kenya (Vihiga)	Maize	(1971)	EC	Estimate of returns to extension, significant impact on yields.
Nagy and Furtan	1978	Canada	Rapeseed	(1960-75)	ES	95%-110%
Pray	1978	Punjab (British India) (Pakistan)	Aggregate	(1906-56) (1948-63)	ES	34%-44% — includes extension 23%-37% — includes extension
Scobie and Posada	1978	Colombia	Rice	(1957-64)	ES	79%-96%
Davis	1979	USA	Aggregate	(1949-59)	EC	66%-100% and 37% for the period 1864-1974.

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Evenson et al.	1979	USA	Aggregate	(1868-1926)	EC	65%
				(1927-50)		95%-110% — lower estimate for technology-oriented research and higher for science-oriented research.
				(1948-71)		45% — science-oriented research and 110% for farm management research and agricultural extension
		(Southern)				130% — technology-oriented research
		(Northern)				93% — technology-oriented research
		(Western)				95% — technology-oriented research
Knutson and Tweeten	1979	USA	Aggregate	(1949-72)	EC	28%-47%, depending on the period analyzed, lower estimate for 13-year time lag between the beginning and end of output impact; higher estimate for 16-year lag.
Lu, Cline, and Quance	1979	USA	Aggregate	(1939-72)	EC	25% — includes extension
White et al.	1979	USA	Aggregate	(1929-77)	EC	28%-37%
Moricochi	1980	Brazil (Sao Paulo)	Citrus	(1933-85)	ES	18%-28%
Pray	1980	Bangladesh	Wheat and rice	(1961-77)	ES	30%-35%
Araji	1981	USA	Integrated pest management	(1978-2000)	ES	An ex ante study in 20 selected commodities, includes extension, rates of return ranging from 191% for soft red winter wheat to a negative return for sweet corn.
Avila	1981	Brazil	Irrigated rice	(1959-78)	ES	Includes extension
		(R.G. Sul)				83%-119%
		(Central)				83%-87%
		(N. Coast)				92%-107%
		(S. Coast)				111%-115%
		(Frontier)				114%-119%
Davis and Peterson	1981	USA	Aggregate	(1949-74)	EC	37%-100% — assumes a 14-year research lag period, analyses the decline in rates of return over the 25-year period: 100% in 1949, 79% in 1954, 66% 1959, and 37% for 1964, 1969, and 1974.

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Hastings	1981	Australia	Aggregate	(1926-68)	EC	Increasing returns for increases in research activities.
Norton	1981	USA	Cash Grains Poultry Dairy Livestock	(1969)	EC	31%-57% and 44%-85% for 1974. (Lower estimates for 9-year re- 30%-56% search time lag and higher for 5-year lag.) 27%-50% and 33%-62% for 1974 56%-111% and 66%-132% for 1974
Sundquist et al.	1981	USA	Maize Wheat Soybean	(1977)	EC	115% assumes a research lag of 6 years for the three crops and in- 97% cludes a research spillover variable to account for the effects 118% of research across state boundaries.
Cruz et al.	1982	Brazil	Physical capital Total investment	(1974-81) (1974-92)	ES	53% 22%-43%
Evenson	1982	Brazil	Aggregate	(19??-74)	EC	69%
Ribeiro	1982	Brazil (M. Gerais)	Aggregate Cotton Soybeans	(1974-94)	ES	69% 48% 36%
White and Havlicek	1982	USA	Aggregate	(1943-77)	EC	7%-36% — includes extension
Yrarrazaval et al.	1982	Chile	Wheat Maize	(1949-77) (1940-77)	ES	21%-28% 32%-34%
Zentner	1982	Canada	Wheat	(1946-79)	ES	30%-39% — includes extension
Avila et al.	1983	Brazil (EMBRAPA)	Human capital	(1974-86)	ES	22%-30%
Cruz and Avila	1983	Brazil (EMBRAPA)	Aggregate	(1977-91)	ES	38% (20% for an EMBRAPA-IBRD project in 1977-82)
Martínez and Saín	1983	Panama (IDIAP-Caisan)	Maize (on-farmresearch)	(1979-82)	ES	188%-332%

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Nagy	1983	Pakistan	Maize Wheat	(1967-81)	ES	19% — includes extension 58%
Pudasaini	1983	Nepal (Bara and Gurkha districts)	Aggregate	(1979-80)	EC	Estimate of returns to extension, no significant results
Smith et al.	1983	USA	Dairy Poultry Beef, swine, and sheep	(1978)	EC	25% 61% 22%
Ambrosi and Cruz	1984	Brazil (EMBRAPA-CNPT)	Wheat	(1974-90)	ES	59%-74% (40% including physical capital)
Avila et al.	1984	Brazil (South Central)	Aggregate	(1974-96)	ES	38% (27% for PROCENSUL I for the period 1977-96)
Bengston	1984	USA	Forestry (Structural particleboard)		ES	18%-22% — includes private R&D
Feijóo *(revised by Cordomí)*	1984 *1989*	Argentina (INTA)	Aggregate	(1950-80)	EC	41% — includes extension.
Monares	1984	Rwanda	Potato seed	(1978-85)	ES	40%
Pinazza et al.	1984	Brazil (Sao Paulo)	Sugarcane	(1972-82)	ES	35%
Roessing	1984	Brazil (EMBRAPA-CNPS)	Soybeans	(1975-82)	ES	45%-62%
Salmon	1984	Indonesia	Rice	(1965-77)	EC	133%
Silva	1984	Brazil (Sao Paulo)	Aggregate		EC	60%-102% — includes extension

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Ayres	1985	Brazil (Parana) (R.G. Sul) (S. Catarina) (Sao Paulo)	Soybeans	(1955-83)	ES	46%-69% — includes extension. 51% 51%-53% 29%-31% 23%-24%
Bare and Loveless	1985	USA	Forestry (Timber)		ES	9%-12%
Bengston	1985	USA	Forestry (Aggregate lumber and wood)		ES	34%-40%
Brinkman and Prentice	1985	Canada (Ontario)	Aggregate	(1950-72)	ES	66% — includes private R&D and education.
Doyle and Ridout	1985	UK	Aggregate	(1966-80)	EC	10%-30% — lower estimate for 1978-80, higher for 1966-70.
Furtan and Ulrich	1985	Canada	Wheat Rapeseed Barley Alfalfa	(1950-83)	ES	29% 51% 22% 14%
Herruzo	1985	Spain	Rice	(1941-80)	ES	16%-18%
Muchnik	1985	Latin America	Rice	(1968-90)		17%-44%
Nagy	1985	Pakistan	Aggregate	(1959-79)	EC	64% — includes extension
Boyle	1986	Eire	Aggregate	(1963-83)	EC	26%
Braha and Tweeten	1986	USA	Aggregate	(1959-82)	EC	47%
Brunner and Strauss	1986	USA	Forestry (Preserved wood)		ES	73%
Chang	1986	USA	Forestry (Loblolly pine)		ES	a benefit-cost ratio of 16 : 1.

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Haygreen et al.	1986	USA	Forestry (Lumber, plywood pulp, and paper)		ES	14%-36% — includes private R&D
Khan and Akbari	1986	Pakistan	Aggregate	(1955-81)	EC	36% — includes extension
Newman	1986	USA	Forestry (Southern softwood stumpage)		ES	0%-7% — includes private R&D
Unnevehr	1986	S.E. Asia	Rice quality	(1983-84)	ES	61%
Westgate	1986	USA	Forestry (Timber, containerized seedlings)		ES	37%-111% — includes private R&D
Wise	1986	UK	Aggregate	(Present)	EC	8%-15%
Haque et al.	1987	Canada	Eggs	(1968-84)	ES	106%-123% — accounts for distortions in product market and the marginal excess burden of taxes on the magnitude and on the distribution of net benefits of public research.
Librero and Perez	1987	Philippines	Maize	(1956-83)	EC	27%-48% and 27%-43% including extension
Norton et al.	1987	Peru (INIPA)	Aggregate Rice Maize Wheat Potatoes Beans	(1981-2000)	ES	17%-38% includes extension. Includes an ex post evaluation 17%-44% (981-87) and an ex ante evaluation (1987-2000) 10%-31% 18%-36% 22%-42% 14%-24%
Scobie and Eveleens	1987	New Zealand	Aggregate	(1926-84)	EC	30% — for a 23-year period over which research benefits accrue, varies from 15% to 66% for lags of 29 to 8 years. Includes extension.
Seldon	1987	USA	Forestry (Softwood plywood)		ES	244%-440%

Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Seldon and Newman	1987	USA	Forestry (Softwood plywood)		EC	236%-438% — marginal rate of return
Sumelius	1987	Finland	Aggregate	(1950-84)	EC	25%-76% — marginal rate for public research only and 26%-77% including private R&D. Both include university education.
Tung and Strain	1987	Canada	Aggregate	(1961-30)	EC	High
Beck	1988	UK	Horticultural crop protection	(1979-2001)	ES	50%
			Hybrid Sprouts	(1979-2000)		22%
Echeverría et al.	1988	Uruguay	Rice	(1965-85)	ES	52% — includes extension and private R&D
Evenson	1988	Paraguay	Crops	(1988)	EC	75%-90% — Marginal rate of returns to investment in extension
Harvey	1988	UK	Aggregate	(Present)	ES	-38% to +4% — includes extension.
Huot et al.	1988	Canada	Swine	(1968-84)	ES	45%
Luz Barbosa	1988	Brazil (EMBRAPA)	Aggregate	(1974-97)	ES	40%
Norgaard	1988	Africa	Cassava Biological control	(1977-2003)	ES	A benefit-cost ratio of 149 : 1
Power and Russell	1988	UK	Poultry feeding	(Present)	ES	A benefit-cost ratio of 78 : 1
Russell and Thirtle	1988	UK	Rape seed	(1976-85)	EC	A benefit-cost ratio of 327 : 1.
Thirtle and Bottomley	1988	UK	Aggregate	(1950-91)	EC	70%
Widmer et al.	1988	Canada	Beef	(1968-84)	ES	63%
Zachariah et al.	1988	Canada	Broilers	(1968-84)	ES	48%

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Table 1. (Continued)

Study[a]	Year	Country (Region or Institute)	Commodity	Period	Method[b]	Results[c] (rate of return)
Evenson and da Cruz	1989	South America (PROCISUR)	Wheat Soybeans Maize	(1979-88)	ES	110% 179% 191% Measures the impact of a research network among the following countries: Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay
Fox et al.	1989	Canada	Dairy	(1968-84)	ES	97%
Schwartz et al.	1989	Senegal (CRSP)	Cowpeas	(1981-87)	ES	63%
de Frahan	1990	Mali	Aggregate	(1990-2010)	ES	1%-25% — internal rates of return, an ex ante evaluation of combinations of on-station and farming systems research, extension and credit institutions, marketing system improvements, and fiscal policy reforms
Pray and Ahmed	1990	Bangladesh	Aggregate	(1948-81)	EC	100%
Seré and Jarvis	1990	Latin America	Pastures	(1987-2037)	ES	Ex ante study assuming a closed economy; 15%-20% return assuming an 11-year lag on benefits, lower estimate with poultry substitution, higher estimate without. Rates of return above 100% when benefits start in year 1 (without lag).

NOTE: The results of many of the studies reported in this table have previously been summarized in the following:
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a. In chronological and alphabetical order.

b. Method used: *ES* = Economic surplus *EC* = Econometric.

c. Depending on the study, these are average or marginal rates of return. More than one value means a range of returns depending upon different assumptions or different periods of analysis. Results are rounded. Results of conducting sensibility tests on various parameters of the models are not presented in this table.

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The same methodological procedures for evaluating research are used in an ex post manner to assess the impact of research, or in an ex ante mode to set priorities. Because of the historic nature of ex post analysis, studies based on this approach have mainly been used as political instruments to secure funding. They demonstrate how efficient past investments were but not necessarily where research resources should be allocated in the present.

According to Ruttan (1987) there have been three generations of studies assessing agricultural research:

1. In the first, efforts were devoted to measuring shifts in production and supply functions.

2. In the second generation of studies, nonconventional factors such as human capital, technology, and infrastructure were researched.

3. The third group of studies consists in more sophisticated attempts to understand how technology influences production, methodological advances on the sources of productivity changes, and applications to neglected areas such as forestry, postharvest handling, and social science research.

Whereas earlier studies have made important contributions to the understanding of the sources of growth of agricultural productivity, most of them have only focused on public research, despite the existence of other sources of increases in productivity. For example, public extension and private research and development (R&D) have (usually) not been accounted for.

In earlier studies, extension and research expenditures were combined on the basis that it is difficult to separate the effects of both activities (see Evenson 1968). Only a few studies have specifically analyzed returns to agricultural extension (Huffman 1978).

The impact of public research alone — without the effects of public extension and private R&D — would probably be much smaller. Furthermore, the potential interactions between public research, extension, and the educational level of farmers; and between public and private R&D complicate the analysis. Certainly, further research to define these relationships and analyze the degree of complementarity between them is needed.

Assuming that the rates of return are reasonably accurate (despite the estimation problems) the high payoffs suggest that agricultural research and extension have been very productive. This also means that had there been more funds for research, the returns would have been lower, i.e., the amount invested has been suboptimal. The explanations of why there is

underinvestment in agricultural research vary among different authors, but this area is beyond the scope of this paper.[2]

Since the pioneering efforts of Schultz (1953) and Griliches (1958) and despite some of the measurement problems listed above, there have been significant developments in the methodology of evaluating the impact of research. Today there is a continuum of methodologies, ranging from "back of the envelope" accounting of crude costs and benefits to more sophisticated cost-benefit, economic-surplus, and econometric analyses. The impact-assessment literature also includes a wide range of approaches, from very aggregate-level studies (with very general results) to the level of the individual project, where selectivity problems may arise (i.e., have only the success cases been selected?).

Most of the earlier studies utilized closed-economy and one-commodity models that did not included trade, multiple commodities, spillovers, and other factors. Current mode's incorporate these factors as well as those relating to interactions among market, agricultural policy, and agricultural research. For instance, instead of assuming free-market conditions, as most previous studies on returns to research have, Alston, Edwards and Freebairn (1988) have examined the effects of government interventions (such as price policies) on the estimated benefits from research and the distribution of these benefits.

When analyzing gains from research, it has been traditionally assumed that research has an effect on supply in only one country. Recent methodological developments assess returns to research (and their distribution) in tradable commodities (Edwards and Freebairn 1984). Also, the effects of research have been evaluated in light of three different stages in the production process: the input-supply sector, a farm sector, and a marketing sector. For example, Freebairn, Davis and Edwards (1982) model the effects of research at one stage of that production chain on other production stages and on consumers.

Two additional cases of recent methodological advances in the area of research evaluation are worth mentioning: gains from research at the household level and the incorporation of social costs in the evaluation of research.

There has been a shift away from aggregate returns to research studies and towards the development of models to examine the distribution of gains

[2] See, among other studies, Hertford and Schmitz (1977), Evenson, Waggoner and Ruttan (1979), Ruttan (1982), Fox (1985), and Oehmke (1986).

between producers and consumers, as well as among different income groups within each class (Scobie and Posada 1978, among others). Farm households (which both produce and consume agricultural goods and which supply and demand household labor) have also been the subject of analysis. According to Strauss (1987), the impact of research on the welfare of producers (lower commodity prices) is mediated by the farm household's role as consumer of the commodity.

As noted before, much economic research has focused on measuring the social benefits of generating and adopting new technology, but there are almost no studies that incorporate social costs into the calculation. For instance, Capalbo and Antle (1989) point out that very little effort is directed to measuring the costs of environmental damage and human health risk. They outline a general evaluation framework and discuss issues in integrating disciplinary research for the measurement of pollution externalities and attaching a value to health effects.

Considering the evolution of the methods to evaluate agricultural research, today we certainly have a much farther reaching set of tools than the ones available two decades ago. Moreover, there are important efforts going on to operationalize them in an the context of less-developed countries. Nevertheless, there are several areas of agricultural research evaluation where additional research effort is needed. For example, Ruttan (1987) has identified the following ones: postharvest technology, production research, private-sector R&D, productivity growth in the input industries, maintenance research, and technology assessment.

Further research on these themes will certainly yield improved concepts and techniques to evaluate the impact of research — and hence a better framework for sound research on agricultural research policy.

Assessing the Impact of Research

This section describes the main issues raised in the papers included in this volume. These contributions can be arranged into two categories: general cases and regional studies.

The general cases include papers dealing with the following:

- the challenges of assessing the impact of agricultural research and of agricultural technology management;
- the measurement of producer and consumer surplus gains from improvements in the quality of crop varieties;

- the concept of excess burden associated with the use of tax funds to support research;
- the question of omitting private-sector research when measuring the impact of public research.

The regional studies focus on Latin America and include papers dealing with evaluating the impact of research at three different levels:

- a regional system (CARDI);
- a country (Peru);
- specific commodities (pastures, cassava).

General Cases

Anderson and Herdt explore the value of an impact study. They argue that given the diversity of types of impact studies, it is not possible to generalize about the effects such studies may have. Although most of these studies have had an important effect on generating support for continued investment in agricultural research, the authors argue that (1) methodologically, most of them are simple accounts of gross productivity gains and costs of research and (2) they focus on the positive cases, i.e., they do not identify common cases of negative returns to particular research investments.

Anderson and Herdt also refer to the challenges of attempting to measure the impact of an impact study. In the case of the recent impact study of the CGIAR system (1984-85), the centers implemented many of the recommended changes. However, as the authors argue, it is still too early to try to assess the impact of that study.

Horton, drawing on the lessons of previous impact assessments, research program reviews, and management literature, discusses the challenges of assessing the impact of international research and its use in managing research. He distinguishes between two types of technology — production and R&D — and the corresponding types of impact — production and institutional.

> Production technology refers broadly to all methods that farmers, market agents, and consumers use to cultivate, harvest, store, process, handle, transport, and prepare food crops and livestock for consumption; R&D technology refers to the organizational strategies and methods used by research and extension programs in conducting their work.

Because the principal output of international centers is R&D technology and their principal impact is at the institutional level, the traditional approach to assessing impact by measuring changes at the farm level is more appropriate for national programs. The central thesis of Horton's paper is that impact assessments are most valuable as a management tool when conducted as an integral part of the research process.

Koppel discusses how to monitor and evaluate the performance and impacts of agricultural technology management. He addresses this matter by reviewing basic issues and strategies in determining what a technology management system is prepared to know, what it needs to know, and how it can know it.

Given the diversity of farmers, resource endowments and constraints, land quality, and level of infrastructure, among other things, agricultural technology management faces significant challenges. Koppel indicates that this diversity is even greater when considering the policy environment of the systems, such as a diverse clientele with equally diverse expectations; agricultural, trade, and monetary policies affecting the impact of research; and an increase in private-sector activities. In this context, national systems are focusing more on site-specific, highly adaptive research and depending less on IARCs. Hence, "the role of the IARCs shifts from products to methods, and the role of national systems shifts from adaptive research on IARC products to adaptive methodological innovation with their own products."

It is against this background that Koppel pictures a research manager defining the system's clients, their demands, the potential supply from the research system, and how the monitoring and evaluation procedures are going to be implemented. With the principle that gathering information should be seen as a means, not an end, Koppel discusses the potential use of evaluation outputs: management, policy modification, and generation of new options, general learning, and conformity to bureaucratic procedures.

In evaluating the impact of a research project, Koppel discusses the need to define the clients, their farming economies, their problems, the strategies they currently use to address these problems, and whether or not the output of the research system is addressing the correct problems and reaching the farmers who actually have these problems. Finally, Koppel emphasizes that the process of monitoring and evaluating the impact of agricultural research is a tool, not a product, and that the important question is not whether the tools exist but which tools to use.

Unnevehr estimates gains in producer and consumer surplus from quality improvements in crop varieties. By using hedonic price measures, he develops a relatively simple way to rank potential quality improvements and to

demonstrate the importance of those improvements to consumers. The paper gives an example of how this methodology can be used to evaluate returns to quality improvement in modern rice varieties.

Unnevehr's methodology would enable many research programs that already evaluate quality characteristics to test the importance of quality measures and to estimate the returns to improving quality with few additional research resources.

The hedonic or implicit prices of quality characteristics are easy to estimate from market samples. After these estimates have been made, they are then interpreted to provide a measure of the value of different quality characteristics to consumers. These values estimate the returns to research for improving quality and can be used to set research priorities by ranking the importance of potential quality improvements and assessing the benefits of research to improve quality in addition of improving potential yield.

Dalrymple reviews the concept of excess burden associated with the use of tax funds to support agricultural research and discusses the utilization of this concept in the context of trends in the use of public funds in the United States. Because almost half of the agricultural research conducted in the US is publicly funded through taxes and because many studies have shown high payoffs to investments in research, it seems apparent that those results could be discounted to take into account the excess burden associated with the collection of taxes.

When reviewing the literature on excess burden and the theory of consumer surplus, Dalrymple finds that some of the assumptions of the concept limit its applicability. For example, most models do not allow for the possibility that tax funds may be used for production-enhancing activities such as research. He also finds that it is difficult to develop appropriate measures to account for the deadweight loss. For example, gross and net measures of excess burden (and marginal and average tax figures, among other things) should be clarified when attempting to quantify excess burden. In addition, it would not be appropriate to discount only returns from research in making comparisons with other forms of public investment.

Dalrymple concludes that although the concept of discounting by the amount of the deadweight loss associated with the use of tax funds is justified in theory, it is a complex concept that is hard to implement because of the difficulty in developing appropriate measures of deadweight loss. Moreover, its degree of influence on rates of return is uncertain.

Agricultural research has traditionally been examined from a public-sector perspective, without considering the role and impact of the private sector.

In the few studies where private research is included, it is usually done in a conventional way, by considering input companies only. For example, other institutional models such as research conducted, or funded, by farmers' organizations and foundations are normally not considered. This has important implications when assessing the impact of agricultural research.

Pray and Neumeyer analyze the implications of omitting private-sector R&D when measuring the impact of public agricultural research. Given the importance of private R&D in North America, Europe, and some regions of the Third World, estimates of the impact of public research that do not account for private R&D may be biased. When the interaction between public and private research is not explicitly modelled, the authors argue, the results of assessing the impact of public research may lead to suboptimal investments in R&D.

Pray and Neumeyer examine potential interactions between public and private R&D and develop a preliminary model to account for the influence of public research on private R&D. Assuming a profit-maximizing firm, three factors are critical in determining the firm's expected returns to investments in research: technological opportunity, the degree to which a firm is able to appropriate the benefits generated by an innovation, and market demand. The public sector influences (directly or indirectly) all of these three factors.

The authors list six possible cases of interactions between public and private R&D:

1. Private R&D does not exist, as most previous studies on the impact of public research have assumed.

2. Private R&D is independent of public research.

3. Public research stimulates private research.

4. Public research decreases the amount of private research.

5. The public-private interaction is so close that they are indistinguishable.

6. Public research influences the direction of private R&D but not the amount of private R&D investments.

The authors use two examples to show some of the dangers of ignoring private R&D when evaluating the impact of public research. They discuss the case of crop breeding in India to show biases using the consumer-producer surplus approach to measure benefits from research, and the US case

is used to discuss possible biases arising from the production-function approach.

The authors conclude that unless it is shown that public research has no influence on the amount of private R&D conducted, it is necessary to include private-sector R&D efforts when evaluating the impact of public research. If this is not done, these estimates will probably be biased and the policy recommendations originated from then may be suboptimal.

Regional Cases

Foster, Ingle, and Clarke describe an action-training methodology used to conduct an impact assessment of the Caribbean Agricultural Research and Development Institute's (CARDI) farming system project in eight countries in the region.

The authors emphasize the need for evaluating the social and economic impact of research and report on the methodology used in an action-training program to introduce impact-assessment skills to agricultural managers.

They define an action-training program as one that is performance oriented, situation specific, systematic, has a capacity-building orientation, and involves training, research and consulting.

Ganoza et al. present results from a study evaluating the impact of research and extension (R&E) in the Instituto Nacional de Investigación y Promoción Agropecuaria (INIPA) of Peru. They address four major issues:

1. the relative importance of research and extension, between different commodities;

2. returns to investments made in research and extension, in aggregate and for individual commodities;

3. allocation of resources between research and extension for different crops and different regions;

4. the impact of improved technologies on factor use, cropping mix, credit demand, and income risk at the regional level.

The authors deal with the first issue by establishing guidelines on how to allocate research and extension funds and comparing them with what was actually done in an earlier period, using a congruence analysis. The second issue is evaluated in an ex ante fashion using consumer-producer surplus analysis. The third issue, a yield-gap analysis of experimental plots, was

conducted to measure the scope for R&E activities. The impact of new technologies on a regional level was researched using a linear programming model.

The economic rates of return to investments made by the Peruvian institute of research and extension were found to be high. Given that estimates of the potential yield and income increases resulting from the transfer of nonvarietal technologies were relatively small, the authors argue for continuing support for INIPA's commodity programs. Availability of credit was a crucial factor in facilitating technology adoption.

Seré and Jarvis estimate expected returns to improved pasture research in the Latin American tropics using an ex ante producer-consumer surplus model. Their results show a very high payoff to investments in improved pastures — in other words, current research on improved pastures is significantly underfunded.

Given that poultry production has increased three times faster than beef production in Latin America, poultry prices are expected to continue decreasing (relative to beef), and hence poultry consumption is expected to increase. A common argument in the region is that this will decrease the demand for beef, which will lower beef prices and thereby diminish the returns to improved pasture research.

Contrary to this, Seré and Jarvis propose a different scenario, where even if increased competition from poultry may reduce future beef consumption, regional beef consumption and production can be divorced, provided that beef surpluses can be exported. They also argue that given the downward bias in world beef prices due to the policies of the developed countries, adjusted (shadow) international prices should be used when setting research priorities.

They found that returns on improved pastures are higher if milk production is included, especially from the aspect of developing pastures for small farmers who engage in joint milk-beef production.

Janssen and Lynam integrate ex ante and ex post impact assessments of agricultural research in an example of cassava in the Atlantic Coast region of Colombia. The authors distinguish between the process of generating technology and how the impact of technology generation is measured.

They distinguish two broad categories in the process of technology generation:

1. research: "a creative process in which innovative solutions . . . are identified";

2. development: "the massification and multiplication of these solutions in a specific situation."

On the measurement of the impact of technology generation, they differentiate between ex post and ex ante approaches. Based on these categories, they argue that because of the creative nature of research projects, they can not rely on ex post evaluation of similar projects; however, development projects that are similar to earlier projects can effectively rely on ex post evaluation.

Against this background, the authors present a more advanced integration of R&D, where ex ante and ex post evaluations are simultaneously conducted in a continuous socioeconomic monitoring process. This is done for a case study on a cassava project where technology generation is analyzed in four dimensions (geographic, range of product activities, commodity, and disciplinary organization). These dimensions are used to forecast the potential benefits of the project and are the basis for the management choices to be made in the project. The forecasts and decisions are, in turn, checked against socioeconomic information produced by project monitoring.

The authors conclude that the integrated ex ante and ex post evaluation approach has been very useful for CIAT's cassava R&D program. They also stress the importance of having multidisciplinary teams (that include economists, anthropologists, and organizational scientists) involved in the ex ante phase of the analysis. Finally, Janssen and Lynam argue that technology generation is induced by the allocation of research resources, as well as by market forces. And because successful technology is closely linked with markets, market development should have a higher priority than the generation of production technology, especially when focusing on improving the incomes of small farmers.

Conclusions

Almost all studies assessing the impact of agricultural research (and extension) have shown high returns to these investments. During the past three decades, most of these studies have shifted from measuring changes in supply and production functions to including nonconventional inputs such as human capital They have also moved to more sophisticated attempts to improve the methodologies used to evaluate research and have expanded the analysis into previously neglected areas, such as the effect of agricultural policies or the potential role of private R&D.

The papers included in this volume reflect some of these new approaches as well as current efforts to shed light into areas that have been overlooked in the past. They also demonstrate the implicit challenges of attempting to assess the impact of the generation, transfer, and adoption of agricultural technologies in developing countries.

Despite the important conceptual and methodological advances achieved in the past, new ideas and approaches to quantify the impact of technological (and institutional) change at the national and international level are certainly needed.

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General Cases

REFLECTIONS ON IMPACT ASSESSMENT

Jock R. Anderson and Robert W. Herdt

Abstract

There are many useful spinoffs from exploring just what a program of agricultural research has achieved. These range from providing investors and other decision makers with pertinent information on the economic value of research, to providing a more complete understanding of what has been achieved, and then sharing this information with all parties to a research system. There are, however, many methodological difficulties inherent in such work and these vary from the challenge of measuring gains to knowledge, through the empirical difficulty of determining productivity effects (especially in relation to "counterfactual" situations), to dealing with attaching a value to the contributions of people involved in research activities. All these methodological issues should be broached. Attention is then turned to the practice of such a study, along with further difficulties that may be encountered and which must be dealt with. These include the difficulties of attribution among different, and sometimes competitive, agents working within what may be several distinct research systems, the possibilities for bias in all aspects of measurement, and the virtue of attempting to avoid (and being seen to be attempting to avoid) such biases. Particular reference is made to the impact study of the Consultative Group on International Agricultural Research (CGIAR) centers. The paper closes with a discussion of the possible impact of an impact study and the wider issues of agricultural policy that surround any analysis of investments in agricultural research.

Introduction

Impact assessment means different things to the many different observers of this latter-day phenomenon, but two broad categories can be identified.

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The first is more concerned with the mechanisms and process of research. Observers with this perspective are interested primarily in what the direct products of research have been. These might be concrete items, such as new varieties of cultivated plants or new compounds that might have some desirable insecticidal or fungicidal properties, for example.

To most observers, however, the second interpretation is much more important, and this focuses on what such direct products (or even some of the indirect ones) have actually led to in farmers' fields, or wherever else research is applied. Even in this perspective, there are many shades of emphasis that can be given to the effects of research. One popular line of investigation has been to look at the effects of the spread of modern plant varieties on crop yields. The green revolution, with its overtly significant effects on intensification and increased yields of wheat and rice in so many of the more favored growing environments of these crops, has led to this emphasis in impact studies.

Yet other aspects of this second perspective look beyond mere yields and crop intensities to the wider economic effects of the adoption of new technology. Here again, there are several levels at which the effects can be examined. The most direct level is to look at what has happened to the incomes of rural households (whether farmers, tenants, or landless laborers) as a consequence of changing technologies.

There are much broader ways of looking at all this, however. The effects such as those just mentioned can be regarded as first-round effects which are only the start of the impact of improved technology on the economy at large. The extra incomes earned by adopters of new technology are quickly circulated through the economy and have usually at least an equal impact on the secondary sectors that variously service agriculture, whether it be for supplying inputs or marketing and processing outputs.

More comprehensive ways of accounting for changes in the technologies used in an economy should not be discounted, although they are somewhat more difficult to deal with in empirical work. The "general equilibrium" effects of new technology are not to be underplayed. These work their way around economies and between economies in subtle but important ways. The effects are manifested in such things as population migrations both within and between countries in response to changes in productivity conditions in various industries. It is not just labor that moves. Other factors of production, particularly capital, are also mobile and move quickly in response to new technologies as they appear.

Given these different views of what constitutes an impact study, it is hardly surprising that people hold rather different views about what should have

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been done and what has been done in impact studies. The difficulties, of course, do not end here and, as is detailed below, there are many diverse opinions about impact studies.

Why Study Impact?

There are surely many reasons for attempting to measure the impact of agricultural research. There is probably a complete spectrum ranging from pure inquisitiveness on the one hand through to investor concerns for the returns on their research on the other. Somewhere in the middle are the operational matters of interest to managers of research seeking feedback on what has been accomplished in order to help them direct the course of future work.

If research itself is a delicate flower-like thing, it follows that any attempt at pontification on aspects of this process must share some similar delicacies. Indeed, without due care, a research program can be analogous to a biological subject in an experiment wherein any attempt to monitor the progress of the biological entity can prove to be so intrusive to its performance that the experiment is jeopardized or invalidated.

It is imaginable that the delicate artistry involved in a research program could be stifled by a system of assessing impact. Some of the latter-day schemes for this are called "monitoring and evaluation systems." If allowed to become too heavy-handed, these may nullify the very phenomenon that was supposed to be nurtured and assessed. Confining attention momentarily to public agricultural research, there seems a clear duty for governments to conduct routine and regular reviews of the effectiveness of accountable expenditures on research.

Investigation of research impacts is considerably confounded by the complexities associated with the slow and uncertain evolution of research effects over time. The research itself takes quite some time, particularly when it is related to the life cycles of crop and livestock species. The research worker takes time to have the imaginative ideas that are worth investigating. It often takes quite a long time to implement these as empirical investigations. Even after the results in the field are measured, subject to the environmental uncertainties thrown up by nature, it again takes time to collate, analyze, and interpret the results.

Even the interpretation itself can be subject to considerable uncertainty and is surely an artistic as well as a scientific matter. A researcher may well be convinced that something significant has been found but then the task is to persuade others that the results are real. There are many processes for this, ranging from peer reviews for professional journals to a variety of forms of

internal and external program reviews. Oftentimes, but surely not always, people expert in the relevant fields are involved in making the difficult judgments required.

Processes such as these are necessarily involved in establishing whether research has contributed to knowledge. Again, all this is only one part of the impact process, although a part important to holders of the first perspective. For the economic advancement of humankind, attention must then shift to the second kind of impact assessment, which involves flows of information outside the research system, itself, through various forms of information exchange, such as agricultural extension services, rural media, etc.

Counterfactual Analysis

Knowledge is growing more or less rapidly in every field. Within the many subdisciplines of agriculture, this is also the case, and while desirable in most general terms because it inevitably contributes to the general advance of agriculture and its productivity, it does create some difficulties for those who would attempt to measure the contribution of specific research programs.

Knowledge is a wonderful thing in that it is not narrowly circumscribed. There are spillovers between every aspect of it, so that as an advance is made in one field, analogous insights are gained in others, and there are also positive interactions between the advances of knowledge in different subfields. There is thus a certain degree of arrogance required for those who feel that they can ascribe particular advances to specified scientific investigative programs. It involves taking a somewhat blinkered view of the world and the well-developed mechanisms for transmitting information between people, nations, disciplines, etc., not to mention the innovative drives of the many diverse agents — and, in agriculture, especially of farmers themselves.

In its purest form, a counterfactual situation is one that would most probably have prevailed in the absence of a specified research activity. At this level of generality, it remains unbounded in terms of time or the flow of scientific information (which has its own inertia in modern information systems). Indeed, modern computer technology has greatly speeded the rate at which such information can be shared amongst people in very wide-ranging areas of geography and discipline.

In raising these issues, we should hasten to add that we do not feel that we have any especially novel answers to the difficult questions. It is our impression that such matters will necessarily continue to depend on the personal judgments of the impact assessors. It is also not really a scientific field in which advance can be expected because there is no scope for making

critical observations of just what the counterfactual situation could have been. Cross-country comparisons are fraught with difficulties in method and information measurement.

Considerations of Human Capital

Contemporary economics places justified importance on human capital as an element of the total capital available for investment and development. Conceptually, this is an insightful breakthrough and can assist in understanding the flows of information within a community and the economic valuation of these flows. Unfortunately, however, a conceptually powerful tool does not always lend itself to ready translation into measurable quantities and improved assessment of just how knowledge is captured and exploited. In looking ahead, one of the fond hopes for the future of economic analysis is that the methods of measuring human capital and its use will be greatly elevated.

One thing is sure: the human capital market is much less than perfect. One observes situations, especially in the developing world, where human capital is placed in a research system that essentially constrains its productivity to zero. Situations of extremely scarce operating funds, stifling promotion procedures, inappropriately pegged salaries, and much bureaucratic nonsense, all play their part in turning potentially highly productive human capital into completely depreciated people.

Other Practical Considerations

Many conceptual problems have already been mentioned and all these are significant in empirical endeavors. There are issues of measurement that must be grappled with as well. At the most basic level, many national statistical services are much less than perfect in their description of the physical and economic environment in which research is conducted. Data on agricultural statistics are notoriously unreliable, and the situation is not always aided for the better through the statutory obligations of nations to report their data through the United Nations Food and Agriculture Organization (FAO).

Attribution

Attribution of effects is only straightforward when there is one effect and one cause. This situation never prevails in agricultural research as there are always many agents that are working more or less together in pursuit of research achievements. Any simplistic attempt to ascribe a measurable achievement to just one measured change on the cause side is bound to fall on rocky ground.

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A key difficulty in this regard is the fact that the many agents involved in research do not work in a simple independent or additive manner. Indeed, some of the most productive sources of energy in agricultural research systems are highly interactive. The relationship between international agricultural research centers and national agricultural research systems is an ideal example of such synergistic effects. Both groups are working towards more or less identical ideals, and they pool a diversity of resources ranging from human capital to biological materials in joint pursuit of common aims. To disentangle the effects of productivity gains that may emerge from such activities is an exercise in futility. Some cases can be identified where there is clearly a dominant partner. In most cases, however, any success would not have been possible without the active cooperation of both parties.

Even these remarks are probably too simplistic in their focus on just two agents. In nearly every case, there are many other research elements around the world that have played their part in establishing the existing knowledge base and being corresponding elements in the wider information system in which any particular research activity is taking place.

Possibilities for Bias

The essentially judgmental nature of much impact assessment has been noted, if not definitively established. Many aspects of science are highly judgmental and agricultural research is no exception. Investigators of impact have to seek advice from the different actors in the research systems and must be aware of the fact that their informants may well be biased for all sorts of good human reasons.

Of course, the impact assessors themselves can be biased and need to be alert to the likely impacts of such bias both on their findings and on the credibility of their findings.

Particularly when an outside body is seeking assessment of the results of their investment in research, it will be important not only to be unbiased but also to be seen to be unbiased. Bias is a rather subjective thing but some primary possibilities for at least being seen to be unbiased can immediately be identified.

In international comparisons of agricultural research productivity, there is a potential national element that can work in two ways. In the recent impact study of the Consultative Group on International Agricultural Research (CGIAR) institutions, for example, an attempt was made to involve national authorities as much as possible in the assessment of what the CG system had done for the progress of agriculture in their respective countries.

Such a strategy has the advantage of increasing the face validity of investment in international initiatives in research to critics of this sort of investment. Needless to say, it does not avoid the difficulties that having "local" observers assess "local" effects may well be driven by other considerations that lead to biases that may be positive or negative in terms of assessing impact. As the architects of this particular impact study, we are unrepentant about our strategy of pursuing such an approach to at least minimize the positive international bias that may otherwise have arisen. Our major regret relates to other aspects of our model.

In spreading a given quantum of resources around a number of country case studies with this orientation (about 30), we necessarily had to make many compromises relative to depth of analysis. Even hiring a national to study the impact of the CG system in a designated country does not make it feasible within a few months to investigate all the subtleties of the human relationships involved nor even to do a decent job on econometric measurement of any productivity effects that may, in principle, be measurable.

Conclusions

To judge the value of an impact study, it is necessary, in turn, to look at the possible impacts of such a study. This may have elements of an infinite regress but it is surely relevant to assessing the benefits relative to the costs of any such study.

The indicated diversity of types of impact studies means that there can be no simple generalization about the impacts of such diverse studies. It is surely important for research managers to keep a close eye on what is happening with their research products if they are going to manage the conduct of research in any useful manner. At the other end of the spectrum, what benefits can flow from an impact study?

There have been many studies of returns to research in agriculture. These tend to be rather simplistic impact studies focused on gross productivity gains and the gross costs of the research programs that are presumed to have led to such productivity gains. Such studies have probably been quite important in the wider political process of generating support for continued investment in public agricultural research. There is no controversy over whether or not most agricultural research constitutes an almost pure public good or whether there is an unequivocal case for public involvement. What is not so clear is the extent of returns on such investments. The studies conducted indicate significantly large positive returns, and notwithstanding the representativeness of such studies, these results may well have led to some of the strong continued support from investors in agricultural research,

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whether they be industrial or developing countries, the World Bank, or other international agencies that assist in providing the wherewithal.

It is a moot point just how representative such studies are. There is naturally a strong incentive for investigators to seek out research enterprises that have been relatively productive. It is not clear that there are any significant rewards for identifying that there are significantly large negative returns to particular agricultural research investments. Such situations, however, surely exist.

Documentary evidence on the impacts of impact studies is difficult to come by. We have observed (needless to say, with more than passing interest) the fallout from the impact study of the CG system for 1984-85. Part of the process of this study involved close interaction with the institutions being studied. During the study, comments received on the role and effectiveness of the various centers were shared with them for comment as part of the process of attempting to validate or disprove each reaction received. Some of these comments were quite critical of particular aspects of the way that the centers functioned, and it was interesting to see the constructive manner in which the centers took action in response to these heightened perceptions of their methods of operation.

Some if the issues involved were quite broad, involving the need to adapt to a more developed infrastructure in many developing countries and to upgrade the services provided by the centers. Many changes were implemented to modify the diverse working arrangements between centers and countries. The accentuated recognition that times had changed since the mid 1960s in terms of the needs of many countries was quickly translated into a concrete program of new activities.

Even the claims implicit in the previous two paragraphs about the impact of our impact study may be too immodest because the centers, as always, have been responding simultaneously to many influences beyond our study. Perhaps we must forever remain ignorant of our impact. Perhaps the main impact will be through the main study document by Anderson, Herdt and Scobie (1988). Since this was published only in late 1988, it is surely too early to try to assess its impact.

Reference

Anderson, J. R., R. W. Herdt and G. M. Scobie. 1988. *Science and food: The CGIAR and its partners*. Washington DC: CGIAR and World Bank.

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ASSESSING THE IMPACT OF INTERNATIONAL RESEARCH: CONCEPTS AND CHALLENGES

Douglas E. Horton

Abstract

Drawing on the lessons of previous impact assessments and reviews of research programs and management literature, this paper attempts to clarify a number of concepts related to impact assessment and its use in managing research. Most impact assessments attempt to measure changes at the farm level and to establish causal links with research. This approach is more appropriate for assessing the impact of national programs than that of international centers. This is because the principal output of international centers is research and development (R&D) technology (not production technology) and the principal impact of international centers is institutional impact (not production impact). Even at the national level, in most cases it is analytically impossible to establish a causal relationship between research and production impact. Ex ante and ex post impact assessments are less useful for research management than are operational impact assessments that are conducted thoughout the R&D process. Impact assessment is most useful when it is conducted within a management framework that clearly specifies the intended clients of research systems and their technology needs.

Introduction

In this paper, the term *impact assessment* is used in the conventional, dictionary sense of "determining the significance, importance, value, or power of an event, idea, etc., to produce changes." During the last quarter century, impact assessment has stimulated considerable interest and a prestigious body of literature in the field of agricultural economics. All centers in the Consultative Group on International Agricultural Research

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(CGIAR) system are now expected to conduct impact studies on a routine basis. The results are to be used for planning by the group's Technical Advisory Committee (TAC) as well as by the individual centers. Aside from the TAC and the centers themselves, at least two other groups are interested in assessments of international research: donors and the national agricultural research systems (NARS) of developing countries (Nores 1988).

Early impact studies were generally of an ex post nature, aiming to measure and demonstrate the benefits of research in order to counteract the initial, largely unfounded, criticisms of the green revolution (Ruttan 1982). More recently, the focus has shifted from the past to the future: What research areas promise the greatest potential impact and thus merit research attention? Ex ante assessment is becoming an important component of formal procedures for establishing research priorities within the CGIAR system (TAC Secretariat 1985).

The ex post studies have generated much useful information on the costs and benefits of agricultural research. Perhaps their greatest value has been to demonstrate the exceptionally high returns to several agricultural research programs, and the substantial underinvestment in agricultural research at both the national and international levels (Evenson 1987).

In apparent contradiction to the high returns reported in impact studies, most program reviews note serious managerial and operational problems within the NARS. Clearly, increased spending on agricultural research in country "X" does not guarantee high returns. In many instances, poor management, not funding, is the principal constraint on research impact.

The apparent contradiction between the high returns to research projects and the managerial problems of research systems has a simple explanation: Many research projects or activities have been extraordinarily successful and have generated significant social benefits; however, sustaining a productive research system that generates a continuous flow of valuable new technology has proven to be difficult. Stated plainly, we know more about how to do research than about how to run agricultural research systems. In more general terms, we are better at handling the technical aspects of development than the institutional aspects.

These statements are borne out by a growing body of evidence contained in two quite distinct bodies of literature: (1) reviews and evaluations of development programs in developing countries and (2) management studies of private enterprises and public-service institutions in developed countries.

For World Bank projects as a whole, the following has been concluded (Israel 1987: 2, 4):

> The physical components of programs have been successful about twice as often as have institutional development components. In the reviews of difficulties and delays in implementation, managerial or institutional problems emerge as the most important causes, although their exact nature is seldom defined and analyzed in detail.
>
> Contrary to expectations, the patterns of results of institutional development programs was stronger by sector, subsector, and activity than by country. The most successful were found in industry, telecommunications, utilities, and finance; the least successful in agriculture, education, and services. Within institutions, technical and financial activities fared the best, while maintenance, personnel issues, and coordination were the least successful.

Concerning agricultural research and extension, the World Bank has carried out a review of 128 projects in 10 countries (World Bank 1983: iv-v).

> The study found marked inadequacies in several countries in their resource allocation to and among research and extension, reflecting weaknesses in planning and monitoring processes in these countries. It also observed more frequent concern in development plans and project documents with the quantity of resources allocated for research and extension than with the effectiveness of their use and their impact.
>
> While the bank has successfully supported the development of physical research facilities, this success has not yet been matched by improvement in the management of these facilities or the development of institutional arrangements conducive to their proper utilization.

Studies of private firms in the USA and elsewhere have shown that research is one of the most difficult activities to manage and that new knowledge (e.g., that stemming from research) is one of the riskiest sources of innovative opportunity (Drucker 1985).

In light of the above, it is not surprising that while individual research projects have generated high returns, many research systems are operating at far below their potential. Agricultural research potentially offers extraordinarily high returns in developing countries. However it also presents some of the most difficult management problems.

What is surprising is that so little attention has been directed to understanding and improving the management of agricultural research in developing countries. In many senses, the research process is treated as a mysterious "black box" in which technologists (hard scientists) employ the modern tools of science to transform human and financial resources into new technologies. Economists and policymakers may set research priorities and evaluate the

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results, but what goes on inside the box remains the province of the technologists. The purpose of this paper is to de-mystify some aspects of the process and to identify some potential avenues for improving the management of agricultural research through innovative assessments of impact. This paper's central thesis is that impact assessment is most valuable as a management tool when it is conducted as an integral and continuous part of the research process. Many of the arguments presented apply to extension as well as to research. For that reason, many references are to research and development (R&D) rather than research alone.

The Global R&D System

Impact assessments are sometimes based on the erroneous assumption that international agricultural research centers (IARCs), NARS, and farmers are closely linked in a linear fashion with technology flowing from the former toward the latter. Nothing could be farther from reality. Agricultural R&D systems are becoming increasing large, complex, and interactive, both within countries and at the global level (Ruttan 1987; von der Osten 1987).

Principal Actors and Linkages

Not only the IARCs, NARS, and farmers, but also many donor agencies, universities, international programs and associations, bi- and multilateral special projects, extension agencies, charitable organizations, and private enterprises are actively involved in agricultural R&D. While they play a strategic role, the IARCs are a very small part of the global system; their budgets represent only about 5% of the total funding for agricultural research in developing countries (CGIAR 1985). Those of us in the international centers usually view the publicly funded agricultural research institutes as our principal partners in development. However, we are not the NARS' only partners, nor are they ours.

Figure 1 illustrates some (by no means all) of the linkages connecting an international center (CIP), a single donor, a university, and a private firm in the USA, and a special project, a university, a private firm, a farmer, the national research institute, and the extension agency in Peru. The situation illustrated here is a highly simplified representation of the real world, in which many more linkages operate.

The multiplicity of linkages, and the fact that technological change builds on the stock of accumulated knowledge — not only that generated by formal research systems but also that generated by farmers themselves[1] — makes it extremely difficult to measure the impact of an international center at the

[1] An important discussion of farmer innovation is in Richards (1985).

farm level. The following example, derived from Franco and Schmidt (1985), illustrates how complex the chain of causation can be:

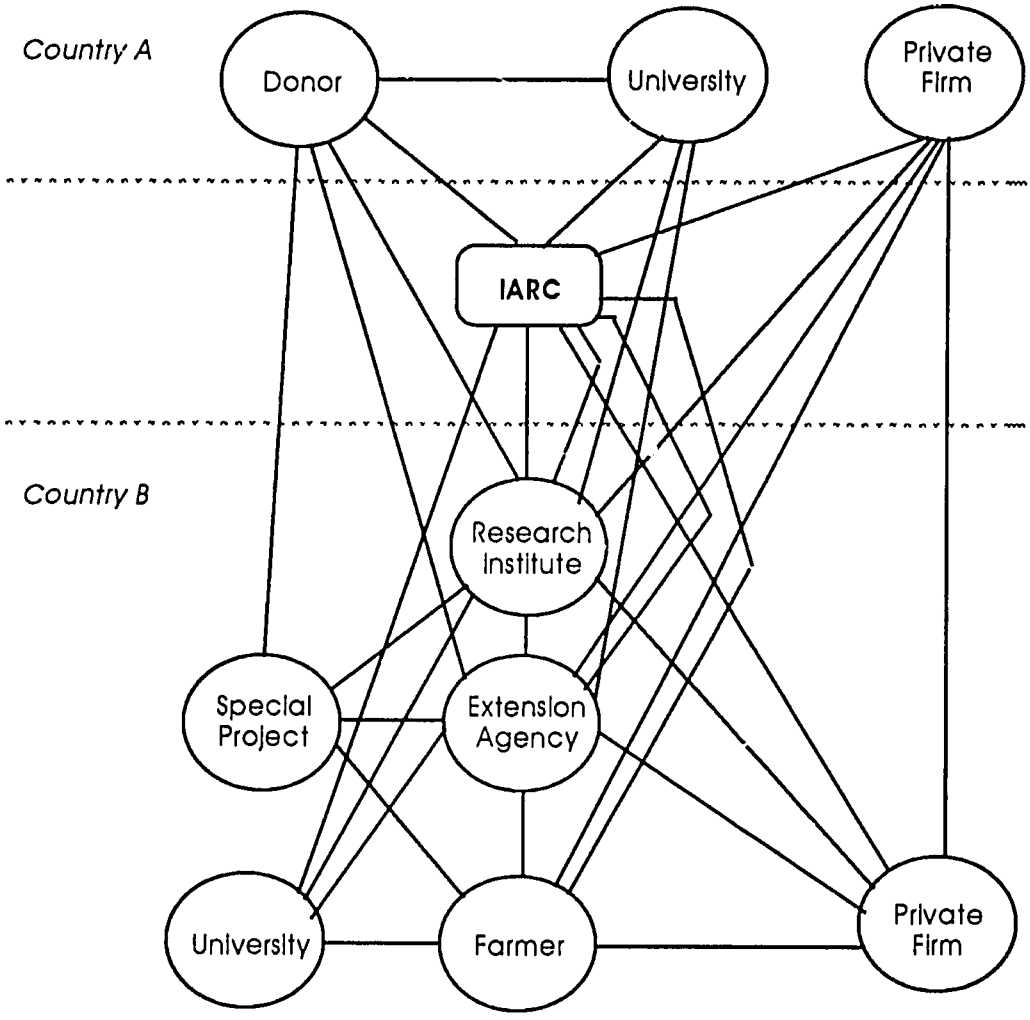

Figure 1. An illustration of some R&D linkages

In the early 1970s the Peruvian Ministry of Agriculture requested that CIP help combat a serious outbreak of bacterial wilt in potato crops in northern Peru. To this end, CIP obtained resistant breeding lines from the University of Wisconsin. These lines had been developed from potato samples sent to Wisconsin by Colombia's National Agricultural Research Institute (Instituto Colombiano Agropecuario: ICA). Part of ICA's work had been financed by the Rockefeller Foundation. Researchers tested potential new varieties on government experiment stations in northern Peru. Two resistant varieties were

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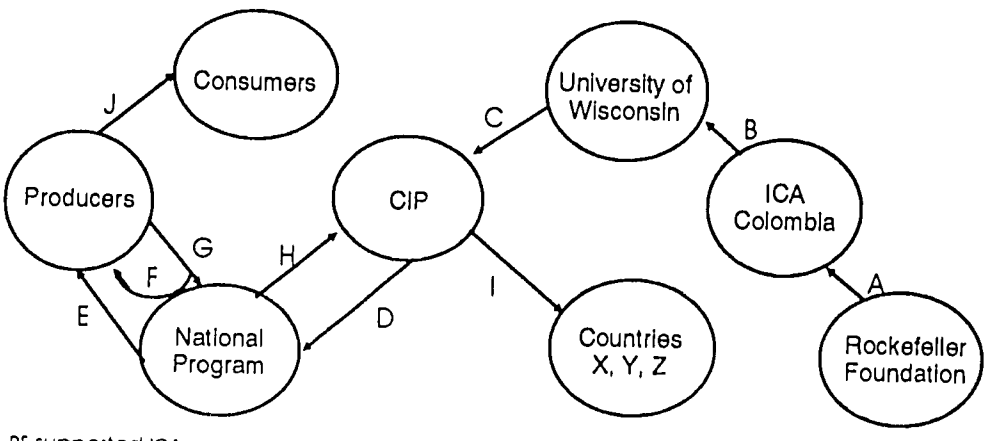
released by the Ministry of Agriculture in the mid-1970s. One of these, called "Molinera," is now among the most widely grown potato varieties in northern Peru.

Farmers grow Molinera in several areas where bacterial wilt is not, and never has been, a problem. They do so because it is early maturing, it sells well, and it has some resistance to a fungal disease, late blight. Researchers had not selected Molinera for these traits. Their presence was coincidental.

From advanced variety trials, Peruvian farmers also kept and multiplied at least two other clones that are not grown in the area. One has gained such importance that it was recently named and officially released as a Peruvian variety. CIP has also distributed this clone to other developing countries as a potential new variety along with Molinera.

Such multiple causation, illustrated for this case in Figure 2 is the norm rather than the exception in agricultural research (Drucker 1985: Chapter 9), making the identification of clear causal links virtually impossible. As noted in a recent, stimulating paper by Murphy and Marchant (1988), the same holds true for agricultural extension programs. The authors conclude that in most cases it is analytically impossible to establish a causal relation between extension services and yields. They propose to shift the



A. RF supported ICA.
B. ICA sent germplasm to Univ. of Wisconsin.
C. Univ. of Wisconsin sent breeding lines to CIP.
D. CIP & Peru's National Program (NPP) selected varieties on Cajamarca Experiment Station & on-farm trials.
E. NPP named & released 2 resistant varieties.
F. Farmers selected 2 more varieties from on-farm trials.
G. NPP named one of these an "official" variety.
H. CIP included promising Cajamarca material in its own breeding program.
I. CIP distributed the new varieties to other developing countries.
J. More potatoes produced in Cajamarca.

Figure 2. An illustration of multiple causation in agricultural R&D: The Cajamarca case

focus of monitoring and evaluation away from agricultural results (yields) and toward the provision of project services and farmers' responses to them (Murphy and Marchant 1988: 6-11).

Research Institutes as Public-Service Institutions[2]

The ultimate goal of R&D is to discover or revise facts (research) that have a practical, beneficial application (development). Private industrial firms can capture a large part of the benefits from their investments in R&D through the sale of patented commodities. In agriculture, private firms seldom have the incentive to carry out R&D activities because the results are improved practices that cannot be patented or marketed at a profit. There are notable exceptions, of course, such as the development and marketing of hybrid maize and the successes of privately owned agrochemical and seed multiplication operations.

The manager of a private firm has a clear criterion — expected profits — for selecting among enterprises, production methods, and distribution strategies. The board of directors also has clear criteria for evaluating the firm's economic performance. In contrast, agricultural research institutes and extension agencies lack these market-driven criteria for decision making.

The CGIAR and many national agricultural R&D systems are moving in the direction of ex ante and ex post impact assessments as surrogates for market prices and competition.

Publicly funded agricultural research is a service, and the institutes that conduct it have many of the same characteristics and management requirements that other public-service institutions, such as universities, schools, hospitals, labor unions, charitable organizations, and a range of government agencies also possess. Management specialists have observed that public-service institutions are inherently less entrepreneurial and innovative than business enterprises. One reason is that public-service institutions are financed from "budgets" provided by donors or taxpayers rather than from the proceeds generated by sales. In other words, they are paid for their efforts rather than for their results. "Success" in public-service institutions is often equated with the size of the budget rather than the value of the products and services provided. This generates a tendency to accumulate programs and expand the bureaucracy. Seldom are programs critically assessed and terminated.

A second reason is that service institutions depend on a multiplicity of constituents who tend to oppose significant change in existing programs or

[2] This section draws heavily on Drucker (1985).

development of new programs which may compete for budgetary resources. For this reason, major changes in public-service institutions usually result from external forces, like funding crises or external reviews, rather than from internal management decisions.

Finally, and most important, a public-service institution exists to "do good." Its mission and goals tend to be phrased in moral absolutes rather than in economic terms that are subject to a cost-benefit calculus. Aiming to maximize rather than optimize, the public-service institution can never attain its goal. The closer it comes, the more effort is required to achieve further gains.

Several entrepreneurial policies have been recommended to enhance the innovativeness and performance of public-service institutions:

- Clearly define the institution's mission.
- Focus on clients' needs and on objectives (the business dimension) rather than on programs and projects (the organizational dimension).
- State realistic goals that are genuinely attainable.
- Focus management on a constant search for innovative opportunities rather than on optimization or expansion of current programs.
- Recognize that all products and services, organizational structures, internal processes, distribution strategies, and even goals have a short productive life span.
- Periodically reassess objectives in the light of achievements (failure to achieve an objective often indicates that the objective is inappropriate).
- Abandon whatever is obsolete and unproductive and terminate programs that represent mistakes, failures, or misdirected efforts.
- Evaluate programs in terms of satisfaction of clients' needs.

Mission and Clients

The first point listed above calls for defining an institution's mission in terms of its clients' needs; the last point calls for evaluating results in terms of satisfying clients' needs. The mission of the CGIAR follows:

> Through international agricultural research and related activities, to contribute to increasing sustainable food production in developing

countries, in such a way that the nutritional level and general economic well-being of low-income people are improved.

Who are the clients of agricultural R&D and what are their needs? In the term "client-oriented research," the client is generally assumed to be "the farmer." However, as illustrated by Figure 1, both international centers and national research institutes have numerous clients. An important function of impact assessment is to identify those groups of clients on which the institute should focus and their needs for new agricultural information.

At the national level, priority clients may include public and private extension services and different classes of farmers in different regions.[3] At the international level, the number of potential client groups is even greater. Clearly, priorities need to be established.

International centers generally view their priority clients to be the NARS — publicly funded agricultural research institutes in developing countries.[4] This has profound implications for the types of products and services that an international center should produce and for the level at which a center's impact should be assessed.

Types of Technology and Types of Impact[5]

It is useful to distinguish between two broad types of technology that may be generated by an agricultural research program — production technology and R&D technology — and the corresponding two types of impact — production impact and institutional impact. *Production technology* refers broadly to all methods that farmers, market agents, and consumers use to cultivate, harvest, store, process, handle, transport, and prepare food crops and livestock for consumption. *R&D technology* refers to the organizational strategies and methods used by research and extension programs in conducting their work.

R&D technologies include scientific procedures for genetic engineering, screening germplasm, disease identification and eradication, and rapid multiplication of vegetatively propagated crops. They also include organizational models, like the integrated commodity program, and institutional strategies for program planning and evaluation, training, networking, on-

[3] *Consumers*, the ultimate beneficiaries of agricultural research, are not clients per se.

[4] In fact, many international centers also work with a range of public and private agencies. In some instances, the NARS have been by-passed in order to achieve a quicker, more direct impact at the farm level. Largely due to the specter of inadequate funding for publicly funded agricultural R&D, international centers are presently actively searching for ties with the private sector.

[5] This section is based on Horton (1986).

farm trials, and interdisciplinary team research involving social and biological scientists (Table 1).

Production impact refers to the physical, social, and economic effects of new cultivation and post-harvest methods on crop and livestock production, distribution, and use and on social welfare in general (including the effects on employment, nutrition, and income distribution). *Institutional impact* refers to the effects of new R&D technology on the capacity of research and extension programs to generate and disseminate new production technology.

With extremely few exceptions, impact studies have focused on production impacts and have overlooked impact (positive or negative) at the institutional level. While new production technologies are of undeniable value, they are not the only, nor are they the most important, outputs of international centers. This is because production problems change over time, and national programs — not international programs — must solve most of them. A stream of new production technologies is needed to solve future production problems and maintain agricultural growth. Hence, R&D technologies that improve the capacity of national programs to generate new production technology can give international programs a substantial multiplier effect.

As Evenson (1987) and others have shown, the greatest beneficiaries of international agricultural research are countries with strong national programs. In fact, strong NARS are essential to the accomplishment of the CGIAR's basic goals. Because of the great variability of farming systems and production problems, national and subnational programs have a comparative advantage in generating production technologies, whereas interna-

Table 1. Examples of R&D Technology and Production Technology

R&D technology	Production technology
Germplasm Advanced lines Breeding strategy	New potato variety
Tissue culture Virus testing techniques Certification	Improved seed
Principles of integrated pest management	Recommended IPM system
Storage principles	Improved storage design

tional programs have a comparative advantage in generating R&D technologies.

The first international agricultural research centers, CIMMYT and IRRI, produced new varieties of wheat and rice. However, shipments of seed — the classical, physical technology transfer — are now only one of several mechanisms used by international programs to achieve impact. Even the new seeds produced by international centers are now best viewed of as R&D technologies, rather than finished production technologies, since they are usually destined for breeding or screening programs rather than for immediate use by farmers.

Center Programs and the Supply of R&D Technology

The CGIAR system is hard-science and hard-technology oriented. The system was created to capitalize on the great potential contributions of applied research to food production that were illustrated by the spectacular impact of rice and wheat breeding on crop yields beginning in the 1960s. It was expected that international breeding and complementary research programs for other crops and for livestock could generate similar impact. It has gradually been recognized that the type of breakthrough represented by the discovery and rapid spread of high-yielding varieties of rice and wheat is the exception, not the rule, in agricultural R&D. Nevertheless, most international centers maintain that breeding and genetics are their most important programs, with other activities considered as complementary.

As evidence of the lack of impact of many breeding programs mounts, attention has shifted somewhat to the "softer" sciences and technologies. In the late 1970s and 1980s, centers experimented with on-farm and farming-systems research approaches as ways to improve the practices and welfare of small farmers in the absence of high-yielding new varieties. In some instances, on-farm research techniques were also used to identify farmers' problems and enlist farmers' participation in the generation and diffusion of new technologies. (Ashby, Quiroz, and Rivera 1987; Rhoades and Booth 1982).

The CGIAR's growing commitment to supplying institutional technology is reflected clearly in the program of the International Service for National Agricultural Research (ISNAR), which has the following goal:

> To assist developing countries improve the effectiveness and efficiency of their agricultural research systems through enhanced capacity in the areas of research policy, organization, and management (ISNAR 1987: 10).

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In the commodity centers, management reviews, ex post impact assessment, and long-term planning are now routine. Senior center staff are also benefitting from a specially designed management training course. The next section discusses some ways in which impact assessment can be used to improve research management and the improved supply of institutional technology to NARS.

Operational Impact Assessment

The current paradigm for impact assessment is based on investment project analysis. It elevates the impact assessor to the level of a project planner (ex ante assessment) or evaluator (ex post assessment), who functions outside of the project itself. Ex ante and ex post impact assessments are most useful for assessing investment projects that have a well-defined technology, a fixed time frame for implementation, a market for output, and a central capital component. Examples are factories and powerplants.

Ex ante and ex post assessments are far less useful in the case of research, which is best treated as a long-term process rather than a discrete project. Research is as much an art as a science. Research processes cannot be clearly specified in advance — they evolve as discoveries are made. The time frame is unpredictable. The practical outputs are difficult to anticipate and generally they are unmarketable. Serendipity is an inherent characteristic of the research process. The better the research, the more abundant the fortunate accidental discoveries. The most critical determinant of the result is not the financial investment but the quality of work, which is influenced by many environmental factors.[6] Hence, in research the relation between costs and benefits is much less predictable and measurable than it is in "standard" investment projects in industry and capital-intensive services like power generation.

Broad priorities need to be set for research before substantial sums of money and valuable human resources are committed to work on specific commodities, factors of production, or location-specific problems. Hence, ex ante assessment is essential. However, managers need to keep potential impact at the center of their thinking throughout the R&D process. As discoveries are made, as clients' needs change and as the environment (funding, economics, politics) evolves, there is a need to continuously steer activities toward those that offer the greatest potential impact.

It is generally believed that the useful roles for social scientists are at the extremes of the agricultural R&D process. Early on, social scientists can

[6] *Environment* here connotes communication linkages, working conditions, and professional incentives as well as the braoder economic and political environment.

generate useful information about farmers' traditional practices. After research is done, they can facilitate technology transfer and measure the resultant changes. Little or no role is seen for social scientists in the operational aspects of research.[7] This view, stated most clearly, and humorously, by James Cock (1979) is still accepted by most technicians as well as social scientists. However, operational impact assessment — working throughout the R&D process to determine the value of new technology[8] to produce changes that contribute to the institution's mission — can contribute significantly to an institution's effectiveness and impact.[9] Operational impact assessments require an interdisciplinary framework and an understanding of clients' needs.

Meeting Clients' Needs: Prescribed and Felt

Scientists — not just in agriculture but in all fields — often work to fulfill the prescribed needs of their clients — those which researchers believe merit attention — rather than clients' felt needs. The experiences of CIP and many NARS in improving potato storage provides a useful example of the dangers of working to solve prescribed, rather than felt, needs. For years, potato researchers and extension agents have worked to promote and improve the storage of consumer potatoes on the erroneous assumption that it would benefit farmers in their areas (Rhoades 1985).

> In the 1970s, storage research and demonstration programs were underway throughout the Andes. The lack of technology transfer and impact was assumed to result from poor extension and farmers' ignorance. In 1977 an anthropologist conducting research on storage in highland Peru found that few farmers were interested in storing potatoes for market because prices were unpredictable. (He also quickly learned another reason why farmers did not store: It was illegal to store consumer potatoes in Peru at the time!) However, virtually all farmers stored seed potatoes, and they were interested in improving seed storage. The implication for management was clear: Research could have a greater impact by focusing on storage of seed, not consumer potatoes. CIP's storage research program was redirected and practical ways to improve seed storage were quickly discovered. This information was communicated to researchers and extension agents in many countries and has been practically applied by farmers as well as by seed programs in at least 15 countries.

[7] *Operational* is defined here as having to do with the operation or working of a system or process.
[8] *Technology* is defined broadly as the application of knowledge for practical ends.
[9] Cases are presented by Rhoades (1985), Horton (1986), and the publications cited therein.

Tapping Knowledge in the "Real World"

There is a tendency in the scientific community to segregate knowledge and technology into two types: "modern" knowledge and technology that is derived from scientific R&D and "traditional" knowledge and technology that has been developed by people at work. The former is considered inherently superior to the latter — biotechnology is better than natural selection; high-yielding varieties are better than native ones; certified seed is better than farmers' common seed. What is often ignored is that most of the knowledge and technology used in agriculture — in fact in most sectors of most economies — has been developed by people working outside of the scientific community. Scientific research is the foundation of vital new knowledge for innovation, yet most knowledge-based innovations have been made by laypeople rather than by scientists or technologists. Drucker (1985: 119) provides an explanation:

> [Scientists and technologists] tend to be contemptuous of anything that is not "advanced knowledge," and particularly of anyone who is not a specialist in their own area. They tend to be infatuated with their own technology, often believing that "quality" means what is technically sophisticated rather than what gives value to the user. In this respect they are still, by and large, nineteenth-century inventors rather than twentieth-century entrepreneurs.

Successful entrepreneurs realize, and capitalize on, the value of "real-world" knowledge and innovation. For example, software developers for microcomputers encourage users to report bugs, problems, and gaps in products and to suggest solutions. The firms reward users who suggest innovations by giving them free, updated software. Updates are then marketed to other users.

Unfortunately, involving users in R&D is less common in public-service institutions like agricultural research institutes. Agricultural researchers tend to view their clients, especially the poorer ones, as lacking in knowledge and technology. Consequently, as Richards (1985) has noted, indigenous agricultural knowledge is "the single largest knowledge resource not yet mobilized in the development enterprise."

On the assumption that traditional varieties should be replaced, seed programs in developing countries usually certify only "improved varieties" that have been officially released by the ministry of agriculture. In fact, many of these new varieties never become popular with farmers. The basic reason is not that farmers are traditional but that many new varieties do not meet local requirements. In North America as well, nearly all potatoes are still traditional varieties; only one modern variety that has been produced by a scientific breeding program is grown on a significant scale.

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Fortunately, in Canada and the USA, seed programs certify any variety that farmers want to grow. Clearly, limiting seed certification to new varieties seriously limits the impact of seed programs in developing countries. One goal of operational impact assessment is to find and capitalize on opportunities generated outside the formal R&D system.

Capitalizing on Unexpected Successes[10]

Scientists, and even businessmen, often fail to take advantage of unexpected successes, preferring to stay on the planned course of action. This can be a fatal error in any field, but especially in a research-based one, where discovery is the goal and the practical applications of discoveries are impossible to predict. The development and marketing of computers provides an example (Drucker 1985):

> In the 1940s, Univac had developed the most advanced computer but decided not to market it for business use because it was intended for science. IBM, which decided otherwise, soon established a leading position in supplying both business and the scientific community with computer equipment.

In agricultural research, we tap only a small portion of our potential impacts, because we ignore, or suppress, unexpected successes. For example, it is well known that farmers often keep seed from variety trials conducted on their farms. In many cases researchers go to great lengths to stop this on the grounds that varieties should not be "released" until they are adequately (read *scientifically*) tested. Yet, the evidence clearly indicates that farmers have a comparative advantage in selecting new varieties that fit the complex local requirements for production, marketing, and use. The example of how the Peruvian Ministry of Agriculture and CIP picked up a new variety from farmers, introduced it into the local seed system and distributed to other countries (Drucker 1985: 4-5) illustrates how unexpected successes can be capitalized on to maximize impact.

Another illustration from Drucker (1985) relates to the seed storage case cited in the previous section.

> Potatoes kept in the light turn green and they can be kept longer before they sprout. For years, the principles of diffused-light seed storage have been well-known by researchers in the Andes, but until the 1970s, no attempt had been made to apply it on farms. In the context of a problem-oriented farming systems project, a field team found that diffused-light storage had a significant impact on the time seed could be stored, on seed vigor, and on subsequent yields. Farmers began

[10] The ideas for this and the following section came from a reading of Drucker (1985).

applying the new technology even before on-farm trials were completed. Capitalizing on this unexpected success, and banking on its potential global impact, the post-harvest team introduced the principle to a number of countries through training, workshops and on-farm trials. The result was widespread farmer adaptation of the technology to fit local needs. Clearly storage principles, not designs (the analogue of technological packages for crop production) were responsible for the impact. This information was fed back into training materials and workshops.

What does this have to do with impact assessment? Crucial to its success was a continuous assessment of approaches — both technical approaches to seed storage and institutional approaches to national programs and farmers. The question was, Which approach is likely to achieve the greatest impact in the greatest number of areas? The methods were usually simple: bull sessions, arguments, back-of-the-envelope calculations, conversations with farmers, simple on-farm trials. The results were seldom published.[11] Nevertheless, operational impact assessment played a key role in this work, which has been CIP's most successful program to date.

Dealing with Incongruities

When a program fails to meet expectations, the usual reaction is to increase efforts to ensure future success. The result, however, is usually another failure. Incongruities between expectations and achievements are often a sign that the goal is unrealistic, that the strategy is inappropriate, or that conditions have changed.

The lengthy, costly experiences of CIP and scores of national programs with seed programs provides a useful illustration. Farmers do not plant potato seed per se but tubers that they have purchased or kept from the harvest of a previous crop. Seed tubers are generally the most costly and problematic input in potato production, representing from 20% to 50% of the total production cost. Seed programs have also been the most costly and problematic aspect of potato improvement programs. More donors and more governments in developing countries have spent more money attempting to establish viable seed programs than they have on any other aspect of potato improvement. The results have usually been far below expectations. The "hardware" aspects of the programs have been reasonably successful: laboratories and greenhouses have been built, equipment has been installed, and seed has been produced. However, most programs have encountered serious difficulties distributing the seed produced, assuring quality standards, and maintaining the program after foreign funding and expertise has been

[11] Rhoades, Horton, and Booth (1986) and several other publications discuss the methods in general, but the assessments themselves seldom produced publication-quality results.

withdrawn. Few seed potato programs have been able to sustain production of more than a few percent of the national seed requirement. The result: whereas ex ante impact assessments place seed at the top ot the R&D agenda, ex post assessments show poor returns to many investments in seed programs.

Operational impact assessments in a number of countries are helping to pinpoint the reasons for failure as well as promising avenues for future concentration. First an example from Peru, based on Prain and Scheidegger (1988):

> In Peru, since the 1940s potato improvement has centered on seed, the goal being to improve seed quality (reduce virus incidence) in the highlands. Potato is the country's major staple food and it is the leading income source of poor small highland farmers. In contrast to expectations, most seed produced was sold in coastal areas which produce only about 10% of the crop and where incomes are relatively high.
>
> In 1977, CIP and Peru's Ministry of Agriculture initiated on-farm research to test recommended technologies under farmers' conditions. Improved seed was the central component of the recommended package. To our surprise, the improved seed performed only a little better than farmers' common seed. Since it cost much more, use of improved seed actually reduced farmers' incomes.
>
> This finding led to a redoubling of efforts to improve seed quality. After several years it was determined that the best possible seed yielded only about 20% more than farmers' common seed. This unexpected, and to many researchers inconceivable,[12] finding stimulated interdisciplinary research on how farmers manage their seed to maintain high quality. Biological research was also begun on the spread of virus diseases and their impact on yields at high elevations.
>
> Efforts in the seed program were split into two separate thrusts: one, following more or less traditional lines, was directed to supplying the needs of coastal farmers. An entirely new institutional strategy was developed to feed a small amount of high-quality seed of native varieties into highland farmers' traditional seed systems.
>
> In the project as a whole, which had the central aim of improving the welfare of small highland farmers, the emphasis has shifted away from seed toward other factors which might have a greater impact. These include tillage and control of soil-borne pests.

[12] Inconceivable because "improved seed" is by definition better than farmers' seed(?!).

An example from South Korea (Horton et al. 1988) illustrates how an incongruity between objectives and achievements can reflect changing conditions, which make it essential to continually reassess the potential impact of both technical and institutional innovations.

> In the 1970s, potato production fell dramatically in Korea. An economic study conducted at the time concluded that this was due to rapidly rising incomes and a negative income elasticity of demand for potatoes. In fact, the decline in production resulted from a collapse in the country's seed system due to uncontrolled infection with virus diseases. Beginning in 1979 a new technical scheme was established, based on modern techniques of virus detection and elimination, on sterile (virus-free) in vitro maintenance, and on rapid multiplication of early seed generations on 15 hectares of land under screenhouses.[13] After screenhouse multiplication and field multiplication on the experiment station, a provincial seed farm, and a private growers' association, certified seed was sold to farmers in other parts of the country. Fields were inspected for virus diseases during each multiplication.
>
> The system has been strikingly successful. In 10 years, largely as a result of the seed program, national potato yields have doubled. Nevertheless, the certification system has never been able to supply more than 15% of the nation's seed requirements. A careful assessment revealed that a significant amount of seed was "leaking" from the formal system each year. It was being multiplied in a parallel, informal system in the private sector. The reason for this leakage was that official prices for high-quality seed were far below the opportunity cost [Figure 3].
>
> The study concluded that whereas the initial institutional arrangements were needed to establish the seed program, these same arrangements are now a major constraint to further increases in potato production and use. Proposals were made for increasing the role of the private sector in seed multiplication and for focusing the NARS's activities on producing basic seed stocks, on quality control and on other high-priority research areas, including post-harvest technology and release of new varieties.

The cases presented in this section are intended to illustrate the utility of a range of types of impact assessments conducted in-house within a R&D program at the operational level. Their principal goal is to improve the operational management of the program, rather than to set overall priorities or to provide quantitative measures of the benefits. Their results may not be scientifically rigorous; they are, however, extremely relevant for research management.

[13] Multiplication in screenhouses was to avoid entry of aphids which transmit potato virus diseases.

Challenges

Introducing impact assessment into agricultural R&D institutions at the operational level represents a significant institutional innovation, and as with all such innovations, there are challenges on both the supply and demand sides of the equation. On the demand side, the principal challenge is to make research instiutions more business-oriented — more concerned with understanding and generating technology that meets client needs. A practical problem in the way of stimulating a demand for operational impact assessment is the belief that scientists know what farmers need. A related problem is the lack of confidence in the ability of the soft sciences — anthropology, sociology, and management — to contribute productively to agricultural research.

On the supply side, there is as yet no client-oriented framework for managing agricultural research in developing countries. Without such a framework, research managers and scientists will continue to find little use for the results of impact assessments, except as sources of information for public relations campaigns.

A suitable framework for assessing institutional impact is also lacking. If impact assessment continues to focus on changes in production, the results will have limited value for managing international centers. Finally, well-

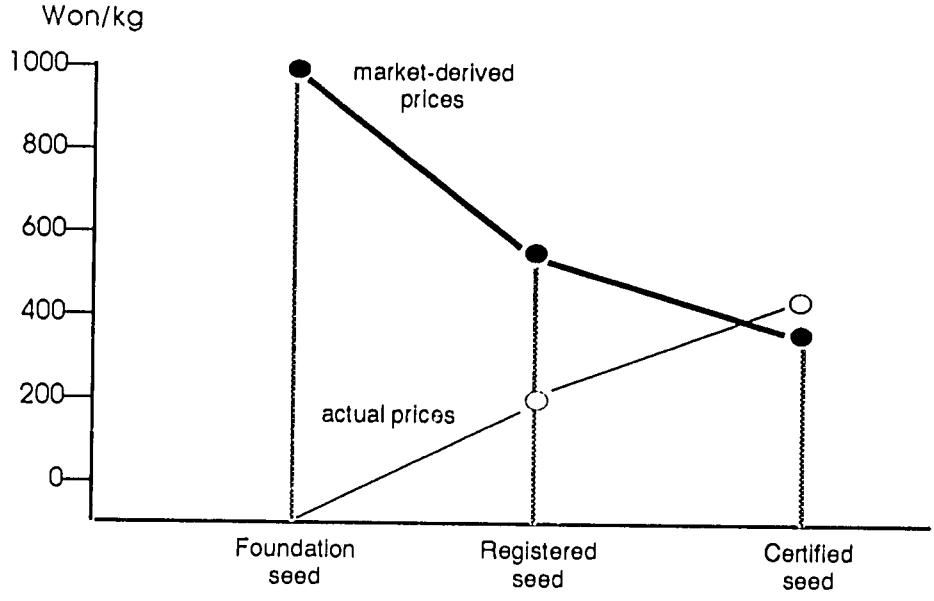

Figure 3. Actual and market-derived prices of foundation, registered, and certified seed

trained managers and social scientists with experience in agricultural R&D are needed — people who can contribute productively to the development of needed management frameworks and their implementation on a day-to-day basis.

"Getting the Business into the Organization"

As noted earlier, a common problem of public-service institutions is their tendency to be preoccupied with internal, *organizational* issues rather than with the external, *business* issues. Scientists tend to become fascinated with the problems they work on and to become so wrapped up in the research process that they loose sight of its ultimate purpose: practical application by clients. As Egan (1987) and others have noted, the central challenge to service institutions is to "get the business into the organization" — to focus on markets, customers, mission, the products and services that satisfy customers' needs and wants, and the environmental conditions (e.g., economics, politics) that affect their delivery and use. Only when an institution is business-oriented can impact assessment contribute significantly to management. The participation of senior managers of the CGIAR in management training courses represents a significant positive step in the direction of making the research centers more business-oriented.

Toward a Management Framework for Agricultural Research

A substantial body of knowledge has been developed over the last 40 years on management of private firms. However, only recently have attempts been made to apply management principles to public-service institutions.[14]

Recent work has focused on the management of urban-based public-service institutions in developed countries. Little attention has been directed to the special needs of agricultural research institutions in developing countries.

An important exception is Israel (1987), who offers two reasons for this. One is that development theory and practice have by and large been in the domain of economists who, with exceptions like Schumpeter, Hirschman, and Libenstein, have been concerned first and foremost with issues of allocative efficiency rather than operational efficiency. Second, the disciplines of management science and development administration have not been particularly successful in tackling the problems of developing countries, much less of agricultural R&D (Israel 1987: 3).

[14] When Peter Drucker wrote his classic management text, The Practice of Management, in 1954, he stated in the opening chapter that its principles were intended strictly for private enterprises. In contrast, in his 1986 book, Innovation and Entrepreneurship, he dedicates a full chapter to entrepreneurship in the service institution.

ISNAR (1987: 18) has identified 12 critical factors that affect NARS's capacity and management:

- interactions between national development policy and agricultural research;
- formulation of agricultural research policy: priority setting, resource allocation, and long-term planning;
- structure and organization of research systems;
- linkages between NARS and policymakers;
- linkages between NARS, the technology-transfer system, and users;
- linkages between NARS and external sources of knowledge;
- program formulation and program budgeting;
- monitoring and evaluation;
- information management;
- development and management of human resources;
- development and management of physical resources;
- acquisition and management of financial resources.

Similar lists of critical factors and suggested remedies are found in numerous program review documents. These may provide a useful starting point for constructing the needed management framework for agricultural research in developing countries. Needed is a comprehensive review of these reviews to extract general lessons for agricultural research management. A serious effort is also needed to adapt relevant principles from the developed-country literature on public-service institutions to meet the special needs of agricultural research managers in developing countries.

Assessing Institutional Impact

Since NARS are the priority clients of international centers, it is essential to have measures of impact at the institutional level. It has been noted by Nores (1988) and others that the distinction between institutional impact and production impact does not facilitate impact assessment because enhanced institutional capacity should be assessed by the value of its output, which

in turn should be assessed in terms of production impact. "Institutional impact cannot be disassociated from production impact. As they interlink, both types of impact need to be assessed as part of the same studies" (Nores 1988: 287).

The same view permeates TAC's present approach to priority setting in the CGIAR system. The important distinction between production technology and R&D technology is recognized, but no serious attempt is made to measure institutional impact.[15]

The argument that institutional impact cannot, or should not, be assessed in isolation from production impact calls into question the validity of all external reviews of agricultural R&D programs. As Norton (1985) notes, review teams practically never have access to detailed information on production impact. Yet reviews of both international centers and national systems are increasingly common, and they present a wealth of information and recommendations on the organization, management, and performance of research institutes.

The solution is not to negate the importance of institutional impact and focus only on production impact but to develop methods for measuring it, based on a general management framework for agricultural research institutes.

One obvious gauge of impact, probably the most relevant one but the one least frequently used, is for an institution to ask its customers what they think. How valuable do the NARS feel an international center's products and services are? The CIP (1984) impact study was based on the simple principle of asking the clients what they thought about CIP's work. ISNAR's annual "User's Meeting" is a mechanism for gauging potential impact through direct interaction with clients.

Needed Institutional Innovation

Improving the management of agricultural research institutes now presents one of the greatest challenges to the development community. Significant institutional innovation is needed to make the evolving global research system more aware of, and responsive to, its clients' needs. Present conditions seem propitious for the needed innovation. However, this will require that a broader dialogue be established, involving not only biological scientists and economists but also the softer sciences like anthropology, management, and organizational sociology. Most important, effective, two-way dialogue is needed with the NARS.

[15] USAID apparently still does not appreciate the importance of institutional impact, and focuses its assessments on production, income, consumption, and the (physical) environment (Kumar 1987)

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THE NEED TO KNOW: MONITORING AND EVALUATING AGRICULTURAL TECHNOLOGY MANAGEMENT

Bruce Koppel

Abstract

This paper presents an operational framework that agricultural support system management can use to determine what it needs to know about its clients (farmers, agribusiness, commodity groups, other government agencies, urban consumers, and international "experts"), how it can find out what it needs to know, and how it can use the information generated to improve priorities, personnel management, and resource allocation. The framework used is called program benefit monitoring and evaluation (PBME). The framework is highly management-oriented, which means it is oriented to the decisions that agricultural technology management needs to make. It begins with simple "self-assessment" methods that help management answer questions such as, What is the mission? What are the capacities? What are the constraints and opportunities in the client environment? What does management need to know (and when) to best mobilize available capacity, overcome (or avoid) constraints, and meet its mission? The self-assessment methods, in turn, are linked to specific monitoring methods with primary attention to capabilities and resources that are already available. This permits management to determine the most efficient and reliable way to meet its information needs.

Introduction

Agricultural technology management is becoming a considerably more complex job. Consider the following questions, as any agricultural technology system manager must: Who are the clients of agricultural research? What must agricultural research do to serve and satisfy these clients? How can a

manager know whether and to what degree a research and extension system is reaching these clients? How does one reconcile conflicting or incompatible demands from different clients on the agricultural technology management system? These are difficult questions and questions that have and will continue to become more difficult. Why? The fundamental reason is that the context in which agricultural technology management functions is changing and the images frequently used to describe that context are becoming less relevant.

Monitoring and evaluating the performance and impact of agricultural technology management in this changing context is becoming a correspondingly more difficult challenge. What makes it even more difficult is not the lack of appropriate methodologies — what is missing are guidelines for choosing and using different methodologies, guidelines that can link the information generated by the methodologies to *both* the understanding needed by an agricultural technology management system as well as the understanding the system can effectively absorb. At present, monitoring and evaluation, when they exist at all, too frequently relate to needs that are not those faced by the agricultural management system.

This paper will address this problem through a review of basic issues and strategies in determining (1) what an agricultural technology management system is prepared to know, (2) what it needs to know, and (3) how it can know it.

The Diversity Challenge

In many parts of the developing world, agricultural technology management systems matured in the 1960s and 1970s in a setting of monocropped agriculture. The "green revolution" brought the benefits of research to the small farm more successfully than before, but the type of farm (and farmer) that did best were rice, wheat, and maize producers, operating in relatively well-endowed agroeconomic environments. It was logical for research to focus on these farms because the potential for payoff appeared highest.

By the late 1970s, attention heightened to a reality that many of these farms and farmers were increasingly doing other things besides growing basic cereal grains. At the same time, in many places real wages appeared to be falling and the demand for seasonal labor was creating difficult problems for a growing rural labor force. A response to both of these issues was a movement to find ways of optimizing land and labor use. Serious interest in farming systems research was underway. However, a more fundamental challenge to agricultural technology management systems was at hand.

In areas that had benefited from green revolution research and extension (and associated investments in infrastructure), the processes of change that were unfolding included agricultural diversification on-farm, household income diversification extending to off-farm sources, and in several places, transformations in land use away from agriculture altogether. In the substantial areas that had not directly benefited from green revolution programming, persistent low productivity coupled with continued environmental degradation was aggravating rural socioeconomic welfare.

In both cases, agricultural technology management confronts diversity — in types of farmers, resource endowments and constraints, classes of land, levels of land infrastructure, sophistication of local technologies, efficiency of market systems, degrees of physical accessibility, etc. However, diversity in the farm environment is only one part of the story. Agricultural technology management also faces an operating environment that is becoming more diverse.

National agricultural system management must contend with a wide variety of potential clientele and "governors," including national legislatures, budget offices, international donors, international agricultural research centers, urban consumers, and a variety of domestic and international commodity interest groups. Agricultural policies have become less important to many agricultural households compared to other policies that significantly, if only indirectly, affect agriculture — notably trade, monetary, and tax policies (Koppel and Zurick 1988). Private-sector activities in agriculture were previously confined to selected chemical inputs for export crops and well-endowed food crop producers. These activities, along with private-sector involvement in extension work as well as marketing and processing for almost all crops, are becoming more extensive and are raising questions about future levels of public funding for the agricultural research system.

Finally, agricultural technology management in many parts of the developing world is undertaken in the context of development projects, frequently foreign-assisted. This is not to say that basic research and extension activities are not conducted outside of development-project environments, but it does say that significant proportions of funds and personnel are in fact programmed in relation to, if not actually under the direct supervision of, such projects.

National agricultural systems are becoming more aware that the challenge of diversity cannot be resolved simply by dependence on the international agricultural research centers (IARCs), a pattern that evolved in many cases during the 1970s. The diversity challenge puts greater stress on site-specific and highly adaptive research capacities at the national level. In this context, the role of the IARCs shifts from product to method, and the role of the

national agricultural research system shifts from adaptive research on IARC products to adaptive methodological innovation with their own products. Beyond this, however, agricultural technology management has to try to maintain its own sense of mission in a complex and not always entirely sympathetic policy and administrative environment.

Against this background, how is a manager supposed to determine who the system's clients actually are, what they want, what agricultural research can or should do to satisfy these wants, and once all that is done (although actually there is rarely ever a fixed determination), how does the manager monitor and evaluate whether the system is doing the things it has been decided the system should do?

A Framework for Deciding

It is essential to emphasize that there is no single method to fill these needs, just as there is no single description of an agricultural support system's relationships to its clientele that would best fit all systems. What there is, however, is a way of looking at the problem and then in a practical sense, deciding what you need to know, what resources you have to know it, and how to use those resources to give you the information you need. The key is to recognize that what you need to know is strongly (although not exclusively) dependent on what you are prepared to learn.

Figure 1 provides a simple schematic framework for analyzing relationships between an agricultural research system and the methods a system will favor to meet its perceived need to understand the effects of its activities. The framework asks the following: *What is the model an agricultural support system maintains to determine what it needs to know about impacts and how it needs to get that information?* The term "model" as used here does not to refer to a statistical or econometric statement or even anything that is especially formal. The term "model" as used here means this: the assumptions and expectations a support system makes about how its activities will accomplish results.

Understanding the model is very important. It tells us how an agricultural support system expects what it does to contribute to the achievement of certain results and goals. It also tells us what a system believes are the factors that can cause failures in the achievement of certain results and goals. Finally, it can also tell us what that system will believe it needs to know to do its job.

Figure 1 asks two questions. The first question is how does the agricultural research system define its relationship to the linkage between what it does (policies and projects) and the effects or consequences of what it does? Two

A System Sees the Role of the Client as a . . .	A system's relationship to the linkage between what it does and the effects of what it does is . . . **Flexible**	**Fixed**
WHO that participates in defining its own needs and interests	Interactive-Based Methods	
WHAT that fits "pre-"defined needs and interests		Indicator-Based Methods

Figure 1.
How an Agricultural Research System Chooses Impact-Assessment Methods

answers are proposed: The agricultural research system can define its role as flexible or fixed. *Flexible* means that the linkage of system activities to consequences is not viewed as fixed, but rather as evolving, and that modification is possible but requires adjustments from both the research system and, presumably, affected clients. The agricultural research system's role is to learn from implementation experience what its most optimal contributions are. *Fixed* means that the linkage of system activities and outputs to consequences is viewed as relatively final, that modification of goals or strategies is unlikely, but inefficiency in implementation can be a problem. The agricultural research system's role is to learn from implementation experience how it can more efficiently administer its chosen (or mandated) activities.

The second question is how does the agricultural research system define the role of its clients in the linkage between what it does (policies and projects) and the effects or consequences of what it does? Two answers are proposed: First, clients can be viewed as a "Who" that defines its own needs and interests. Alternately, clients can be defined as a "What" that fits predefined needs and interests.

The principal implication of Figure 1 is that certain classes of impact assessment "methods" are more compatible (and are more likely to be seen) with certain types of agricultural research systems in the sense that what these methods offer and how they offer it are consistent with what the agricultural research system wants to know and how it wants to know it.

Why and how do systems make these choices? To answer this question, four issues need to be addressed:

1. What does an agricultural technology management system need to understand about a specific clientele group?

2. How can the process that links what the agricultural technology management system is doing to the farmer be visualized?

3. What are the ways an agricultural technology management system can utilize monitoring and evaluation information?

4. Because, as noted earlier, agricultural technology management frequently is undertaken within the context of agricultural and rural-development projects, how have different project management organizations addressed the first three questions in terms of strategies and methods for monitoring and evaluation.

Understanding the Clientele Group

The first step in thinking about a transfer process is thinking about what it means to adopt a technology. The challenge of diversity requires putting concerns about technology adoption more clearly into the context of the needs and characteristics of specific client groups. The "limited resource farmer" will be used here as an example.[1] Technology adoption among any kind of farmers can be reduced to some deceptively simple questions:

1. What is being adopted?

2. Who is doing the adopting?

3. Why is adoption occurring, and implicitly, why is adoption not occurring?

4. What happens after adoption has occurred?

It is important to emphasize that a good deal of what is known about how these questions can be answered has been learned within the context of

[1] The phrase "limited-resource farmers" usually refers to farmers who are less commercially oriented than those with whom agricultural support systems have commonly worked. Such farmers expect their farming operations to directly support a broader range of household food and energy needs. They may not be incorporated into anything other than purely local commodity markets. They may be relatively more reliant on their own agricultural experience and orally transmitted accumulation of local agricultural knowledge than they are on research station science, formal extension, and printed bulletins. They may live in communities with relatively less commercial and marketing infrastructure or government services, fewer opportunities for off-farm employment, and possibly a higher average incidence of unemployment, underemployment, episodic malnutrition, and disease. They are unlikely to be anything other than marginal users of manufactured agricultural chemicals, and the chemicals they do use are most likely to be fertilizers.

sponsored programs of technology diffusion, usually among farmers who do not share most of the characteristics commonly associated with limited-resource farmers. This is not to suggest that such programs have not reached limited-resource farmers. They have. However, there are some generalizations that need to be qualified or even reconsidered when limited-resource farmers are defined as a primary group of adopters.

1. What Is Being Adopted?

This question has been easiest to answer when it has been possible to identify a specific material item (such as a seed variety) that is either adopted or not adopted. In the last two decades, however, agricultural development has not been restricted to the diffusion of specific material items alone, but rather there has been an increase in deliberate efforts to encourage the adoption of packages of technologies, technology management practices, and, in many instances, financial and marketing practices as well. Policymakers in the agricultural support systems may have been very clear about how these different parts fit together, so clear that they might have considered the packages to really be one item for adoption. Certainly the descriptions of the numerous "integrated" projects that were and are the vehicles for these efforts communicate the image of a merged package.

The farmer's view of this package, however, is not always the same as the support system's. Some parts will appear attractive. Other parts will elicit less interest and enthusiasm. In fact, the farmer may not be seeing a package at all, but a collection of individual items. The reverse has also been true. An agricultural technology management system believes it is recommending a specific, discrete item for the farmer's consideration. What the farmer may see, however, is not a discrete item but rather a solicitation to make commitments on time, land, and labor that go beyond what the support system realizes it is asking. The question that needs to be asked is, *Is enough understood about the limited-resource farmer and the limited-resource farm enterprise to know what it is that is actually being recommended?*

2. Who Is Doing the adopting?

Many of the generalizations that can be drawn from recent experience with the adoption of agricultural technology assumes that the adopter is a farmer, an individual, usually a male head of household. If you saw the decision to adopt as a onetime decision, it would not be unreasonable to focus on the individual you thought represented the farm enterprise and who, in some visible way, could be identified with the decision. Supporting this was a strong preference, if not an actual bias, in work by extension agents and evaluation specialists alike, to look for and find individual male heads of household who were predefined both empirically (often through sampling

frameworks which instructed interviewers to select and interview male heads of household) and conceptually (usually through theoretical frameworks that assumed the farm enterprise consisted of a single male manager who had family labor available for allocation). Today, ideas in this area are changing. Much greater attention is being given to the role of women in agricultural decision making and, beyond that, to the role of families and community organizations in decisions about agriculture.

More careful consideration also needs to be given to the distinction between the adoption of technology that follows from a single adoption decision or a number of adoption decisions (Koppel 1976). If the latter is the case, as it can be for any collection of tasks or technology that has recurrent costs, it may be necessary to acknowledge the existence of different decision processes and even different decision makers for various aspects of adoption commitments. In such circumstances, many decisions are often decisions of degree (not simply "accept-reject") that can vary over time. If, indeed, a *series* of decisions is operating, what is the relationship between prior decisions and subsequent choices? How is this relationship influenced by what is being adopted at any given point in time as well as by who the effective decision makers are at different points in time?

An important point about adoption decisions follows. The process seen from the perspective of the system of technology generating and disseminating may be characterized as adoption. But the process the farmer sees may be better characterized as *adaptation* — incorporating and modifying something into fuller compatibility with the farmer's specific situation. In the context of a discussion about what is being adopted, it is quite natural to be concerned with the corollary questions, From whom and from where is the technology adopted? However, if the discussion is about what technological strategy is being *adapted*, then attention shifts quite naturally to the corollary questions, By whom and to what is the technology being adapted?

3. Why Does Adoption Occur?

Adoption research offers two broad insights on this issue: *motivations* and *attributes*. Research on individual motivations for adopting new technology has been extensive and has concentrated on answering two questions, Are farmers price-responsive? Are farmers risk-averse? The research says repeatedly that farmers are price-responsive, which can be translated to mean that technologies that reduce marginal costs or increase average returns will be favorably viewed, all other things being equal. The research on risk offers the general insight that farmers, operating as they do in an aura of some uncertainty, determine and apply what amount to risk premiums as part of their evaluation of new technologies.

Ecologists and anthropologists have also examined motivations for technological change among farmers, and they point to additional factors. Research on stability and uncertainty emphasizes that household subsistence and security are intimately tied to the agricultural enterprise. Consequently, farm households are visualized as trying to minimize episodes of variability (in output primarily) that can ultimately threaten the integrity of the family unit. Research on social, cultural, and religious values that can influence perceptions about the generation and disposition of surpluses, the allocation of family labor, land-use intensity, financing production costs, etc., emphasizes that choice of agricultural technology is deeply embedded in a sociocultural context.

Research on price responsiveness and risk aversion has tended to concentrate on the more surplus-oriented farmers. In terms of Figure 1, the "who" in this research has been predominantly the individual farm household head, although in recent years this research has been extended to time and labor allocation within the farm household. Research on stability, uncertainty, and values has tended to concentrate on the more subsistence-oriented farmer. Again, in terms of Figure 1, the "who" has tended to be the farm household, with broader kinship relationships and village affiliations often considered as well.

Research on motivational aspects of the adoption of technology has been considerably better at explaining the adoption of specific technological artifacts (seeds, fertilizers, tractors) than it has at explaining the adaptation patterns for these artifacts or the adoption and adaptation of associated practices (for example, complementary private investment in land infrastructure or reallocations of family, community, and hired labor). For similar reasons, motivational research has not provided too many useful generalizations about the dis-adoption or abandonment of technology previously accepted. A special example is technology succession, the replacement of one technology by another. A well-known illustration is the rapid turnaround in seed variety choice demonstrated by large numbers of Asia's rice farmers.

4. What Happens after Adoption Has Occurred?

Traditionally, adoption research has not concerned itself with this question, at least not as an empirical matter separate from attempts to explain why adoption occurs. An alternative view, however, has developed. Sometimes called "technology assessment," this view is that adoption research should not be restricted to the questions, Will it be adopted? Who will adopt it? When will they adopt it? Why will they adopt it? Two additional questions also need to be asked (Koppel 1981), How will the technology work? What happens if the technology is adopted?

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Awareness has broadened in the last decade that demonstrating the working of an agricultural technology in the carefully controlled environment of the experiment station really does not indicate whether the technology will work in other environments nor (even more important) what kinds of variability can be associated with the performance of the technology when it is inserted into different agroecological and farm-management environments. As a result, on-farm research is becoming an accepted element of the agricultural research process. However, the distinction that is really at issue is not *where* the research is physically taking place, but rather *on what terms of reference* the research is being conducted and evaluated. Using station methods on-farm really proves very little unless the methods used on-station are also close to farmer methods for the farmers thought to be the end-users of the technology under development. As agricultural research moves towards greater immersion in on-farm research, it needs to become more deliberate about what kinds of farms *and farmers* it chooses to work with. The important point is that the adoption issue surfaces *before* the technology research, when we ask, For what types of farms *are* we working? — not *after* the technology research, when we are implicitly in the position of asking, For what types of farms *were* we working?

Closely related to this question is another question that in one sense is commonly asked and in another sense is very infrequently asked: *What if the technology is adopted?* The way in which this question is commonly asked is through assumptions and expectations about benefits and costs that will accompany adoption. Increases in income, employment, and output, or reductions in pests and weeds are already discussed. Other aspects of the question have not been so commonly encountered. For example, the environmental impact of adopted technologies is often not given particularly serious attention. This is partly a result of focusing on individual farmers and farm households as adopters and neglecting to aggregate and ask what the cumulative environmental impact might be if concentrated adoption occurs in contiguous areas. It is also a result in some cases of inadequate knowledge about what kinds of environmental impact may even be likely.

Sometimes the focus is more on who it is hoped will adopt the technologies than who actually might do the adopting. Identification of the latter group requires clarity about what kinds of resources (human, material, land, capital) will be required to really acquire and make effective use of the technology, how the extension and diffusion systems are operating or are likely to operate in diffusing the technology, and what all this means for (1) which farmers will have early access, (2) which farmers will be most assured of getting supervision or assistance for early problems of acquiring and using the technology, and (3) how patterns of adoption by one group or type of farmer may influence the feasibility, rate, patterns, and costs of adoption by other groups and types of farmer.

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The question, what if the technology is adopted? — is really the question, what if the technology is *utilized*? The issue is not the accept-reject decision, but the graduated decisions involved in adapting the technology to the existing farming enterprise and resource endowment. How well does an agricultural support system understand what kinds of variability are probable on the farm and what major consequences of that variability are likely, in terms of the technology's performance as well as the farmer's welfare?

For example, experience with chemical pest control shows that under certain circumstances, farmers may misuse this technology. They may mishandle or improperly mix chemical materials, application may be done incorrectly or at the wrong times, and so on. Such farmers have adopted chemical pest-control technology, in the sense that they have acquired some of the material artifacts associated with the technology, but practice or utilization is not as hoped. In some cases, the result is uneconomic, a consequence the farmer may also see, resulting in substantial reduction or even termination of use, i.e., dis-adoption. In other cases, the result may be unhealthy, except that the farmer may not know this until it is too late.

Issues of utilization are strongly behavioral issues. They underlie the importance of understanding the farmer and the farm enterprise quite strongly from the farmer's perspective. This doesn't mean that everything needs to be understood on a farm-by-farm basis. What it does mean, however, is that it *is* necessary to understand those relationships within the farmers' systems that most strongly influence how new technologies and practices will interact with the farm enterprise already in place.

Returning to Figure 1

Several strategies are available for translating the ideas and questions raised thus far into some operational procedures for learning about adoption, adaptation, and utilization. However, such procedures cannot be considered independently of the institutional and programmatic context in which they will function. This means understanding how the research system, in particular, and the agricultural support system, more generally, visualize their relationships to farmers and what this visualization implies for the type of information and information acquisition that are likely (see Figure 1).

Basically, a system has two choices. Where an agricultural support system is firmly oriented to utilization and adaptation objectives, then it will be inclined to need an understanding of the farmer's context, provided in some sense, on the farmer's own terms of reference. This plus the tendency for objectives for utilization and adaptation to establish requirements for recurrent support means that the support system will need to place itself in some *interactive* mode with the farmer. For example, the redefinition of relation-

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ships between on-station research, agricultural extension, and on-farm research that characterize the institutional innovations of farming systems research can be seen as illustrations of efforts to improve the form of communication between farmer and scientist.

If the support system's orientation is more towards acceptance objectives, then it will be inclined to need profiles of farmers and farms to facilitate monitoring and evaluation of acceptance rates, usually in terms of correlations with specific *indicators* of farmer characteristics. Many innovations and improvements in program-monitoring systems are illustrations of efforts to increase the availability and accuracy of such indicators for purposes of program management.

If interactive research proceeds from the assumption that it is the *difference* in farming systems that mandates intensive understanding of specific systems, then indicator research proceeds from the assumption that it is the *common* characteristics of farmers and farms that mandate extensive understanding of numerous systems. Both types of research generate and support understanding about adoption, but they generate two different kinds of understanding. Interactive research does better at understanding what is happening and why in specific situations. It is less useful for providing generalizations that can be applied to numerous other situations. This can be a problem for national agricultural support systems that are not characterized by a capacity for regional variation in research trials and extension strategies or are otherwise accustomed to implementing standardized and uniform national recommendations.

Indicator research does better at explaining what might happen in a large number of situations, what can be called generalizable knowledge, but it may be less adept at providing much insight about any specific situation. This can present a problem to more regionalized or decentralized national agricultural technology management systems, particularly if regional parts of the system are expected to develop an understanding of adoption that can directly support the formulation of national programs as well as the development of their own more area-focused programs.

Visualizing Linkages between Activities and Accomplishments

Evaluating Objectives and Actions

The most common type of evaluation starts from the question, What happened in comparison to objectives? Depending on how the question is answered, it is possible to make some judgments about whether a program

was a success or not. But within this well-known type of evaluation there are actually many versions.

Figure 2 illustrates a number of ways in which objectives can be evaluated. Two kinds of distinctions about objectives need to be made at the outset. The first is between objectives that are explicit and objectives that are implicit. Explicit objectives are those that are openly and precisely stated at the outset (for example, increase per capita income from $200 to $225 within 12 months). Implicit objectives are often not stated openly, and often they are not precise — they may, in fact, be very ambiguous and unclear (even to the planners of the program!). An example might be the following: increase per capita income from $200 to $225 within 12 months but do not cause any loss of income by those who are comparatively well off. The last part of the sentence is the implicit objective.

Clarity of Objectives	Project Cycle Domains			
	Input	Transformation	Cost	Effect
Explicit				
Implicit				

Figure 2. Evaluating Objectives and Actions

The distinction between explicit and implicit objectives is not meant to say that somebody is hiding something, but rather to remind ourselves that programs evolve for a variety of reasons. Along the road there will be numerous compromises and trade-offs. The implicit objectives that underlie the compromises and trade-offs are often carried into the project. As programs are implemented, implicit objectives can become more obvious. They may even become quite explicit!

The first distinction between explicit and implicit objectives was based on the clarity of the objectives. The second distinction refers to which parts of the project cycle the objectives refer to. After all, a project is usually not just one activity with a clear beginning and end but many, often overlapping, activities. We can think of the project cycle in many ways. Here is one way:

1. *Inputs.* What goes into a project? This is usually expressed in financial terms, but it can refer to whatever else is required to make a project operational (for example, staff, equipment, supplies).

2. *Transformations.* All programs and projects assume that inputs are transformed in some fashion to yield outputs. Money becomes seeds which become plants which become money and food. Staff become technical assistance which becomes rehabilitated pumps. How and where these transformations occur is often the main preoccupation of project and program management and organization. Consequently, *how* transformation occurs can be a target of both explicit *and* implicit objectives.

3. *Outputs.* What comes "out" of a program? This is the most common focus of evaluation objectives. It asks how many extension visits were made? How many kilometers of road were built? How many fertilizer bags were sold? Outputs refer to those activities, or goods and services, which are the direct outcomes of input transformation in a project.

4. *Effects.* What are the results of a program's outputs on people? On some set of goals? On the program itself? You may be thinking that there is no difference between this category and the former "outputs" category. But an example will illustrate the point. In many countries, there are elaborate efforts to get fertilizers and related chemical inputs to farmers so that production will be increased and economic returns to farmers improved. Getting the fertilizer to farmers is an output. Increases in the production and economic returns are effects of the outputs. We all know of cases where the fertilizer left the warehouse, went to the farmers, but was not used correctly, or went to the wrong farmers, etc. The distinction between outputs and effects is very important because it makes it possible to ask two very important but different questions:

- *Did we produce the outputs we wanted?*

- *Did the outputs have the effects we expected?*

Many evaluations of the "evaluating objectives" type do not make this distinction. So there are many instances of programs judged successful (lots of output) without really knowing what influence they had on anyone. An example might be a warehouse construction project where we know how many square meters of floor space were built but not who is using the space and for what purposes. We also have examples of numerous programs that are judged as less successful (not enough output) but which have had significant effects. An example might be a rural training program where the number of people trained was less than planned but those who were trained applied what they learned and benefited accordingly.

The more complete versions of the framework for evaluating action toward objectives devote attention to what can be called *conditional assumptions.*

What are conditional assumptions? When we think of the project cycle, we also make assumptions about things that will and will not happen while the project is going on. We assume that budgetary support will not be removed. We assume that other projects will not interfere. We assume that the problem the project is attempting to resolve will not stop being a problem before the project is finished. We assume that the people we believe will benefit from the project's outputs will actually want those outputs, and so on. There are two types of conditional assumptions:

1. those that refer to operations *in* projects (e.g., the budget will be managed properly);

2. those that refer to operations *of* projects (e.g., an irrigation system will provide water).

Exercise 1

Look at Figure 2. Take a project with which you are familiar and try to specify the objectives in each box. Are there any inconsistent objectives? Are objectives in some boxes especially difficult to identify and specify?

The importance of conditional assumptions is that they inject an element of contingency into project assessment — the project will work (if our assumptions are not violated).

Why is all this important? There are two broad reasons. First, project performance may reflect interaction or a lack of interaction with certain external factors. For example, a project to improve the marketing of fertilizer for rice production will probably work better if government-supported extension efforts are oriented to effective use of the fertilizer and if government price policies ensure that farmers can afford to buy fertilizer. A project to train paramedical village workers will ultimately depend on continuing cooperation from the professional medical community.

A second broad reason lies in the question of project autonomy. A project, as a set of organized activities, can be viewed as an attempt to control a group of resources in such a way that certain outcomes can be predicted and attained. But can you think of any project that is completely autonomous — that is totally unaffected by factors over which it does not have any influence or control? We can state the issue as follows: For any project, there will be certain outputs and effects whose determination is external to the resources controlled by the project and other outputs and effects whose determination will be largely internal to the resources controlled by the project. For example, if you have anything less than a free hand in staffing or financial management, then your input and transformation objectives will need to be

modified to reflect the constraints that are present. If the project will only work if certain policies are changed or existing policies more rigorously implemented, then the transformation and effect objectives may need to be modified to reflect these contingencies.

Exercise 2

Look back at your response to exercise 1. For each cell in Figure 2, ask what the conditions or assumptions were upon which the objectives are based. Consider conditional factors that are external to the project and conditional factors that are internal. Are some of the objectives you identified in Figure 2 now showing up as being quite sensitive to certain assumptions and conditional factors? Do you know of cases where changes in external or internal conditions led to modifications or changes in one of the "objectives" boxes?

Evaluating the Decision-Making Process

A second common type of evaluation can be called "evaluating the decision-making process." Here the emphasis is not on outputs and effects alone, but on process, on *how* outputs and effects are achieved. In presenting this framework (Figure 3), we again need to identify two dimensions. The first, which is similar to the explicit-implicit dimension of the "evaluating objectives" framework, asks, How similar or dissimilar are the *formal* or *prescribed* processes from the *informal* or *actual* process? For example, one can ask, Did small farmers play the role assigned them in decision making about *X*? One can also ask, Who played the most important roles in decision making about *X*? The difference is between what happens and how (according to the program-planning documents) and what *actually* happens and how.

It is important to recognize that formal and informal decision making usually coexist. When a project contains decision-making arrangements that cross several organizational settings (e.g., a village, a state government, a

The Decision-Making Process	Decision Domains		
	Program	Benefits	Costs
Formal			
Informal			

Figure 3. Evaluating Decision-Making Processes

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national agency), the project is combining several arrangements of power, influence, and decision making. In these circumstances, the project may represent an agreement about how to proceed that can work *in general*, but will not work for all cases that may arise during the course of project implementation. This can happen for at least two reasons.

One reason is that not all the details of project implementation can ever be foreseen (as anyone who has ever been involved in a project knows so well!). A second reason is that the agreements that were negotiated when the project was being started may no longer work because the relationships among those who made the agreements have changed. Distributions of social and economic power in a project's context can change. New distributions of power can operate to get things done, as well as to prevent things from happening. As these things happen, and they often do, a project's formal decision-making arrangements may not change, and they may not need to change. The question is, Can anyone take the initiative to "informally" get things working again? We would have to look at informal decision-making arrangements because formally renegotiating all the agreements may be too much a burden.

One dimension of a framework for "evaluating the decision-making process" is the formal/informal distinction. The second dimension can be called the participation dimension. This dimension directs attention to the actors in programs and projects. It covers several important issues:

1. *Who made program decisions?* This is a very large question, one that applies across the operation of entire programs. In practice, it is typically broken down into four questions. First, decisions about the allocation of input resources. Second, decisions about the transformation of input resources. Third, decisions about the distribution of outputs. And fourth, decisions about the achievement of effects. The difference between formal and informal process in this category is between who makes decisions according to plan and who makes decisions *in fact*.

2. *Who benefited?* The formal side of this question asks, What benefits accrued to those who were the object of the program outputs? But the informal side of the question asks, To whom did benefits accrue? Many evaluations ignore the second side of this question, and while it doesn't necessarily invalidate conclusions drawn from asking only the first half of the question, it may dramatically misstate the total effects of a program. It is like reporting the score of a basketball game between team *X* and team *Y* by saying, "Team *X* scored 80 points." That is a lot of points but without knowing how many points team *Y* scored, it is difficult to say whether it was enough points to win.

Exercise 3

Look at Figure 3. Fill in the figure for a case you know. When you fill in the "formal" and "informal" rows, are you surprised by how important the "informal" parts are? Is informality more important on one column (e.g., program) than another (e.g., costs)? Compare this exercise to exercises 1 and 2. Do you want to reconsider what you said earlier about objectives in light of what you say about decision-making processes here?

3. *Who paid?* The same consideration raised for who benefited applies here as well. Who was supposed to pay? Who was supposed to bear which costs? Who did? This question as a whole is generally underplayed in most evaluations. It is not the same as asking how much particular outcomes cost, since it refers not to aggregate costs but to the *distribution* of costs.

Evaluating Program Levels

This type of evaluation is based on the premise that the kinds of activities being evaluated are not all the same. We can say that activities are the basic building blocks of the many kinds of subject matter being evaluated. Activities in turn can be grouped into projects. It is a project that links together diverse activities and to which most objectives are applied. Finally, the linking together of diverse projects can be called the composition of programs. This classification may seem perfectly obvious to you, but consider its implications for the first two evaluation frameworks. If, for example, we are talking about the rural-development program of country *X* (among the projects of which there is one on increasing the productivity of rice farmers, and among these activities there is one involving the distribution of pesticides), is it proper to apply the same objectives for inputs, transformations, outputs, and effects to program, projects, and activities? If the answer is "no" (which would very likely be case wherever the program, project, and activity were not all one activity), then which objectives belong where? If there are expectations about the involvement of rural households in decision making concerning where outputs will go, is it reasonable for the same expectations to be applicable at all levels — including the management of the fertilizer warehouse or the recruiting of engineers?

Which expectations are appropriate at what levels? What are the implications of potentially conflicting objectives? Can a "participatory" activity be expected to operate without difficulty in a "nonparticipatory" project? If not, what are the likely stresses on participatory objectives and processes?

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Many people think that evaluation is a straightforward matter. You look at the objectives, you compare performance, and you make a judgment as to whether or not performance was adequate, measured against the yardstick of objectives. Evaluating levels exposes the superficiality of this viewpoint. Even for "traditional" projects, deciding what the appropriate objectives are is obscured by the failure of program developers to state all objectives, to state objectives clearly, and to state objectives consistently. The approach of evaluating by levels begins from this body of interacting objectives and seeks to explore the implications of decisions and actions on some levels for decisions and actions on other levels.

Exercise 4

Take a specific activity you are familiar with and describe the it (from its inception to its completion or current state) in terms of decisions about budgets, staff, vehicles, priority areas, etc. made at "higher" levels and how these decisions influenced the way your activity actually took shape.

Evaluating Consequences

One way to look at what really happened is to trace a project's output and look at where it went. This represents what can be called a first-order assessment: Who got the benefits and how does this compare with who was supposed to get the benefits.

We can go further and ask, What are the second-order or "spillover" consequences? In many cases, so-called second-order consequences are more appropriate indicators of the accomplishment of explicit objectives, particularly at the project and program levels. For example, agricultural development projects want to increase farmer incomes. They do this through a chain of outputs. They increase farmer productivity. How do they do this? They increase farmer access to productive technology, credit, and markets. How do they do this? They build farm-to-market roads, make technology and credit available, etc. One output depends on another. Income is increased through a chain of effects that are expected to follow. The farmer uses the technology and the technology works. The costs of using the technology require the farmer to borrow capital, which the farmer does. The farmer can market the produce at a good price. The farmer's income increases. One effect depends on another. The final result is not a direct effect of the project, but an indirect effect. What needs to be done is to identify intervening linkages from program output to effects, establishing the plausibility of the intervening linkages — the probability that the links in the expected chain of effects can and will occur.

One way of conducting second-order and spillover evaluations is on a cross-sectional basis; that is, for a given time period you look at changes of a first- and second-order nature simultaneously. But that carries with it a very important assumption — that change is transmitted "instantly." In some cases, this is a reasonable assumption. The analogy of falling dominoes is an example. Knock down the first and the last will go. For example, using pesticides kills insects. The transmission is not literally instant, but it the duration of time is short enough to make it feasible to examine both the first- and second-order consequences within the same time period.

Another version of this extension of basic evaluation is multiple time horizons. We can say that the lengths of time necessary to expect certain changes to become apparent (if they are going to occur and if they are going to be attributed indirectly or directly to some initial program output) will be variable. For example, a program may involve an activity that trains 20 people to repair irrigation pumps. Those who stay through the entire training would belong in the category "successfully trained." But of these, most live in smaller towns where getting a job repairing irrigation pumps can be quite difficult. It takes anywhere from six months to two years. So there is another time period for a second-order objective: getting jobs. Finally, the competence of pump repairers is judged within a six-month probationary period after they are hired. So that represents yet another time period for evaluating whether the training was appropriate and sufficient.

The question of multiple time periods becomes especially appropriate when we are dealing with first- and second-order effects that hinge on utilization of program outputs or that require the presence of various complementary factors. First, when you are dealing with utilization questions you may engage in "intermediate assessments," carried on while the program is still ongoing or has just concluded. Second, you can embark on a much more difficult, but feasible, course: attempt to define and measure strong indicators of likely future utilization, signposts of strong enough probability that you can say with some confidence that utilization at such and such levels during the next X years is likely. This is difficult because you have little to go on and you cannot use current utilization by itself as such a signpost.

Many programs have complementarity assumptions built in, but their implications for evaluation are often overlooked. Complementarities can represent the intervening linkages through which second-order effects will be transmitted: no complementarities, no second-order effects. It is often that simple. One implication for evaluation purposes is that it becomes necessary to specify how long we can wait for exogenous factors to operate as we expect.

Exercise 5

In Figure 2 you identified objectives for effects. Take the same cases and trace out, step by step, how the project gets from outputs to first-order effects to second-order effects and so on. Are the chains longer than you first thought? What about the time scale as you move down the chain? One point that would be particularly important to observe is where one step in a chain is dependent on the prior step having reached a certain level, not just occurring. Another point that will be important to note and interpret is where actually getting from one step in the chain to another assumes that certain external factors will operate in certain ways. Do you see any links like that? Finally, are you noting that some links that should be there are not there, that is, are not given adequate attention in the project's strategy?

Utilizing the Results of Monitoring and Evaluation

Assuming that an agricultural technology management system knows where it is on Figure 1 and that it has reasonably explicit responses to the issues represented in Figures 2 and 3, and also that it is capable of a candid self-assessment of the skills, resources, and time that may be available for any monitoring and evaluation efforts, what can and should be done? The focus should first and primarily be on the kinds of understanding needed. Consequently, it is essential that *information-gathering methodologies be seen as the means, not the end.* That is because what is needed most is not a minimum base of compatible information, but more fundamentally a *minimum base of useful understanding.*

The notion of useful understanding is not complete, however, unless we ask, useful for whom? To answer this question, it is appropriate to turn to the issue of how the outputs from monitoring and evaluation are utilized.

Five broad types of uses for evaluation outputs will be discussed: management, policy modification, new option generation, the learning mainstream, and archival. The five types are not mutually exclusive.

1. Management

Ongoing evaluation can provide management with the information it wants to better perform the tasks it has set for itself. Usually, the content of management utilization evaluations are defined principally by those areas management controls directly and for which it has direct accountability. For evaluations oriented to continuing use by project management, the basic objectives that guide task definition are not altered; what is open to modification is how the tasks are performed. Management utilization, therefore, is a decision-oriented use of evaluation outputs and can be characterized as

an "early warning" system for decisions that may go wrong, decisions that will need to be made, and decisions that will work out better than anticipated.

2. Policy Modification

Using evaluation outputs to support modification of policy and project directions is also a form of management utilization, but here management is in a position to initiate more fundamental adjustments: objectives are open to reinterpretation, thus facilitating task redefinition. The idea of using evaluation outputs to modify policy is constructed around a very important characteristic of any program or project life cycle: successive iteration and adjustment of objectives and goals. What start out as broad and rather ambiguous objectives are successively redefined into more operational and usable guides to activity. The information needed to chart this iterative redefinition can be built into the evaluation questions.

3. New Options

Using evaluation outputs to generate new options involves a deliberate effort to conceive and develop new objectives, not simply to find better operational definitions of existing objectives or more efficient ways of implementing existing tasks. The utilization of new option generation and of policy modification can be very close in the sense that each considers the implications of what has transpired for what should come next, rather than rigidly staying with a sequence that may be progressively less satisfactory. An example would be the assessment of an irrigation program. Many irrigation programs run into difficulty on canal maintenance. This may not be an objective of such programs per se but the revelation that canal maintenance is a problem can lead to the development of subsequent programming in that area. There are rare but existing cases of programs that undertook revisions in midstream substantial enough to be labelled metamorphoses into new programs. This type of utilization can emanate from an existing program where objectives are seen as significantly misdefined, inappropriate, or trivial. New option utilization is the most subtle form of using evaluation outputs because it stretches outputs beyond the scope of the program being evaluated to the middle of the problem area itself. The focus adds "what" questions to "how" questions.

4. The Learning Mainstream

Interpretation of the learning mainstream says that the evaluation may not contribute to decision making about any particular project and potentially not even about any particular problem area. Instead the evaluation contributes to a broader understanding of social change and social intervention.

There are many examples of this kind of evaluation utilization. Often it is openly academic, that is, it is a utilization by academics.

5. Archival Utilization

Using evaluation outputs to fill the archives somewhere is admittedly a residual category, but the characterization is not meant to be pejorative. The literal interpretation says that (in a very fundamental sense) many evaluation outputs have no *direct* use. They are obligatory elements of a project cycle, but they do not enter into decision making. Since they do not enter into decision making, they assume a cosmetic quality: they make programs look better because they are there, whatever their content. They satisfy external requirements or expectations (be sure to send us a report, but nobody is quite certain what happens to those reports, although there is plenty of evidence of bureaucratic vengeance when the reports are not submitted!). In these situations, evaluations will often be packaged in very appealing formats (elaborate brochures, lots of tables, etc.). This type of utilization is not a decision-oriented utilization; it is a "conformity" utilization which may or may not provide input for utilization in one of the four modes we have already discussed.

Experiences in Monitoring Project Impacts

Figure 1 and the discussion that followed it have drawn attention to how a project or program and its participants *visualize* (1) what the benefits a project is to generate actually are, (2) who the beneficiaries of the project are, and (3) what will link the benefits to the intended beneficiaries. This section asks, How have agricultural and rural-development projects addressed the issue of learning about project impacts? A series of case studies that were produced for just this purpose provide illustrative material (Koppel 1984).

Focusing on Indicators

Benefit monitoring and evaluation can focus on indicators, i.e., attributes assumed to represent the social, technical, and economic conditions a project seeks to affect. The disadvantage sometimes encountered with indicators is that they can be proxies for theoretical concepts that give the indicators content. This can lead to problems when the indicators are used in contexts not consistent with the theoretical concepts. While interpretation can always proceed in such cases, the interpretation may rest too heavily on the indicators' conceptual content and what the indicator presumes empirical reality is, rather than what might actually be happening.

For example, measuring income can be difficult in areas where the relative importance of money and wages, barter and home production are undergoing fundamental changes. In the Barani Area Development Project in Pakistan, very little of what is produced in the project area is currently being traded outside, but remittances from residents working in the Middle East are beginning to monetize formerly nonmonetized relationships within the project area. Income measurement in this case is proving difficult and what measurements are obtained are unlikely to be stable or comparable between different economic groups or over time even within the same group. Similar problems are faced in the Nepal Small Farm Development Project (where poor farm households and landless laborers who are only marginally involved in exchange relationships outside their valleys are intended to benefit) and in the Pahang Barat Integrated Area Development Project in Malaysia, which involves resettling subsistence households and encouraging their transformation into commercially viable farm operators.

Focusing on Beneficiaries

In beneficiary-based monitoring and evaluation, it can be troubling to decide what the boundaries of the beneficiary system are. The Farm Organization Support Services Project in Malaysia assumes that if it can meet approximately 30 percent of the projected need for farm mechanization equipment in the project area, the demand for mechanization services will increase to a level sufficient to generate a significant private-sector response capable of meeting the remaining 70 percent. How much attention should be given to monitoring the problem the project initially believed the intended beneficiaries have? In the case of the Farm Support Services Project, the assumption is made that a labor shortage in the project area is constraining agricultural development and land investment; hence, there is a need for mechanization. However, if the factors causing the labor shortage were, for whatever reason, to abate, could the project's emphasis on mechanization, evolved to solve a labor shortage, become instead part of the cause for a problem of increasing rural unemployment?

Any project makes some assumptions about the behaviors that will characterize users of project outputs. These behaviors may be associated with user endowments (such as education or land resources) and alternative opportunities for employment of these resources (often assumed to be zero). Should the status of these endowments and changes in alternative demands for these assets be monitored to determine if the originally expected behaviors can realistically still be anticipated? If the project doesn't have a way of "testing" the continuing validity of its most crucial assumptions about beneficiaries, will a project ever "know" that the violations of the assumptions are invalidating the project's strategy? However, given the scope and complexity of the problems affecting the rural poor and the tendency of many

projects to claim some recognition of this complexity, would expecting such broad-scoped monitoring and evaluation be asking too much of project management?

Visualizing Benefits

Visualizing the benefits a project is generating is often implicit. A development project may have been deemed feasible because economic benefits were identified and valued as exceeding projected investment costs. However, once the project gets started, project management tends to focus less on economic or financial justification and more on problems of implementation — determining and protecting management's scope of responsibility, staffing, financial resources and budgetary procedures, material supplies, coordination, contracting, etc. In such circumstances, benefits and beneficiaries become ultimate, but distinctly distant, concerns that often are not given detailed attention.

Thus, in irrigation projects in Bangladesh, Pakistan, and Sri Lanka, it is assumed that farmers will organize as needed to distribute irrigation water. In crop-intensification projects in Bangladesh and Burma, it is assumed that farmers will buy and use fertilizer. A common logic of benefit flow and utilization is this: the responsibility for benefit delivery lies with the executing agency doing its job. Benefit utilization will not be a problem if the benefits are there to be utilized by the intended beneficiaries. But how can an agency be certain it is reaching the intended beneficiaries? How can the agency be certain that the intended beneficiaries are prepared to play their role in terms of investment, land allocation, etc.?

In many cases, the degree of precision a project can consistently achieve in verifying eligibility criteria is very rough. Thus, as one agency explained, information is collected about beneficiaries "not strictly in a formal matter but some data is collected in a haphazard manner and used." In the Pakistan Aquaculture project, the desire is present to do more (in this case in terms of systematic beneficiary surveys) but less is done because the "lack of trained persons to manage and conduct these surveys and then to interpret and use their results is likely to be a major constraint"(Ansari 1983: 5).

Perhaps the first step in the development of a formalized capability to monitor beneficiaries is illustrated by the Serajgonj (Bangladesh) Integrated Rural Development Project:

> Under SIRDP, there is virtually no regular system to collect data on the effects of the project on the beneficiaries. These are mostly collected through tour-notes, observation reports (Karim 1983: 7).

This is a characteristic pattern for the agency implementing the project. In the Pabna Irrigation and Rural Development Project, also in Bangladesh, the executing agency is willing to use administrative records generated by other agencies. Data about the project area from the Ministry of Planning are used, as are sample surveys on cropping patterns and land use from the Soil Research Laboratory. These data might convey information on yields, cropping intensity, input use, changing land values, and so on.

Some changes or modifications are sometimes made in the Pabna irrigation and Rural Development Project on the basis of information or data obtained in this way when negative effects on the beneficiaries have been ascertained (Salam 1983: 11). However, project management still maintains that the most direct and reliable way to know the status of the project's intended beneficiaries is not through these indicators.

On contacting farmers in the field during execution of the Pabna Project, the results of the benefits received by the farmers are acknowledged but no records of these results are maintained by the project at the moment (Salam 1983: 13).

The Nepal Command Area Project offers another example of an executing agency using a variety of information sources in a somewhat informal mix. This project is an agricultural-intensification project focusing on the distribution of seed and fertilizer. The overall number of farmers buying seed and fertilizer can be monitored by project management through sales records, which is essentially implementation monitoring of project outputs. The quantities of seed and fertilizer actually reaching farmers in specific locations can be ascertained through records maintained by village councils as well as from sample surveys implemented by the executing agency's field staff. Periodically, a meeting is held in each village by the project manager to find out whether or not farmers are getting benefits reasonably. They discuss the hindrances to getting benefits from the project activities, and project management initiates action based on the results of these meetings (Gujuryal 1983: 6).

The project manager also sends letters "asking for suggestion from the literate farmers" (Gujuryal 1983: 7). The virtue of the approach, the person-to-person mode of learning about the beneficiaries, is also a potential liability. The project manager has many other responsibilities. Relying only on himself to gain a direct sense of the detailed benefit flow and utilization situation can be impractical and even counterproductive if it interferes with overall project implementation.

Some agencies attempt to go further and develop methods for systematically acquiring and processing timely and credible information on benefit flow and

utilization. These attempts are significantly influenced by the capacity of staff to employ these methods and by the ability of project management to recognize discrete management decisions and then to identify and use information that can improve those decisions. An example is the development of sample-survey-based benefit-monitoring systems.

One approach to building and using survey-based benefit-monitoring systems is to contract the work to an outside organization. This may be the best alternative when developing an internal capability is not a realistic option. A major issue in such cases is whether the agency will actually accept responsibility for the analyses generated. In the Kirindi Oya Irrigation Project in Sri Lanka, for example, a very capable local university contractor is in place. Analyses are submitted periodically by the university contractor and forwarded to the project's central coordinating committee. The committee typically asks its members with interests in the topics covered by a study "to consider it." The contractor does not make a direct presentation to the committee, nor is there any formal system for following up the reports or the recommendations they may contain. Is this adequate utilization?

Another strategy is to develop an internal capacity to generate, process, and present benefit-monitoring information. In the Phitsanulok Irrigation Project Stage I area in Thailand, a pilot effort in benefit monitoring is underway to generate timely information for use by project management at the project level with the aim of improving coordination among agencies involved in the delivery of agricultural inputs (Chullasuk 1983: 2). The project-planning division of the executing agency, the Royal Irrigation Department (RID), has a project benefit-monitoring unit (PBMU). In the Phitsanulok pilot project, surveys are designed by the PBMU and implemented by the Phitsanulok Operations and Maintenance Unit under PBMU supervision. Three surveys are conducted each crop season (before transplanting rice seedlings, after transplanting, and after harvesting) on a total sample size of 216 (3%) of the total farmers in the project. Special attention is given to indicators that do not vary from season to season and to data-collection formats that are amenable to rapid (72 hours) and simple processing. The Phitsanulok exercise is seeking to determine a level of benefit-monitoring activity that can be implemented by a project's operational staff and that can address significant project management needs. In this case, project management has to make decisions about water allocation and service distribution. To make these decisions effectively, it needs to know how farmers have been affected by prior decisions and what farmers are planning to do.

A question that remains is whether the Phitsanulok exercise is doing more to demonstrate the feasibility of down-scaling large surveys than it is to demonstrate effective information utilization by project management. In this case and another similar case (Allah River in the Philippines), project

management currently is not using more than a small portion of the information generated, nor is it prepared to address matters raised by the information that are outside management's responsibility. For example, in the Allah River case, the National Irrigation Administration (NIA) is responsible for irrigation system construction, operation, and maintenance. Agricultural-development support services (such as extension) within the irrigation system are not NIA's responsibility. Although most monitoring information concerns agricultural problems, NIA and the Ministry of Agriculture have not established working relationships that would support, in effect, monitoring the ministry's performance by the NIA.

A related issue is the question of who does the evaluation? One project manager worries that when outside firms do evaluations, the product suffers because outside firms tend not to understand important project details. However, few executing agencies could afford, or even see the need for, an internal capacity to evaluate projects. One project manager expresses the point in a way that is widely shared although not commonly admitted: Projects have no system for doing or even seeing benefit evaluations "except those which are taken up by donors at the end of project life and reports are published by them and sent" (Ansari 1983: 16).

Agency leadership may simply not believe that benefit evaluations are needed. A visualization of benefit flow and utilization that is common is that the executing agency is responsible for benefit delivery. It is consequently assumed that benefit utilization will not be a problem if the benefits are there to be utilized by intended beneficiaries. The Allah River case from the Philippines illustrates this position: t role the NIA plays in the formulation of policies on the prioritization of national development programs notwithstanding, the implementation of impact evaluation schemes seems inappropriate for NIA to undertake (Mejia 1983: 21).

Getting Started

Exercise 6

Construct a version of Figure 1 that applies to your overall program. Then, build versions of Figures 2 and 3 that apply to your program. Finally, go back to Figure 1 again and, in the light of what you did for Figures 2 and 3, try to map where different components of your program are on Figure 1.

An agricultural technology management system needs to go through certain steps that together constitute building the system's visualization of how its activities affect its beneficiaries. These steps include asking some basic questions about the kinds of responses that are expected from farmers in the technology-transfer process; thinking clearly about relationships be-

tween inputs to the program, outputs from the program, how the organization and management of the program transforms inputs to outputs, and what factors influence the effects of the program's outputs on both intended and actual beneficiaries. The question of which methodologies are used cannot be asked or answered independently of this visualization and the resources and skills the program is prepared to commit for monitoring and evaluation purposes. Nor can the question be answered without a candid recognition by the agricultural technology manager of how monitoring and evaluation information will be used.

Once all this is done and however it is done, an agricultural technology management program needs to develop, in some form (see Figure 1), a baseline understanding of:

1. who the primary end-user clients for the program are;

2. what characterizes their farming enterprises and household economies;

3. what their existing problems are;

4. what strategies they currently choose to address these problems.

Any impact-assessment system will need to continue to monitor these four points along with a fifth point:

5. is the output provided by the agricultural management system addressing the correct problems and reaching the farmers who actually have these problems?

In the following sections, categories of understanding that might be needed in many cases are illustrated through a list of questions. The questions are not items for inclusion on a survey questionnaire, but rather examples of areas of information that might need to be developed and maintained.

Describe the Project Area

1. What are the existing production systems in the area? What are the roles of these production systems in supporting the income, employment, food needs, and life-style of people in the area? What are, in order of importance, the major, directly productive, natural resource-based activities in the area? What happens to the outputs from these activities? Are there significant variations in output between activities in crop and livestock production? Given different agroecological zones and variations in farm sizes and production levels, what are the existing rates of return from production systems?

2. What are the characteristics of the production-support system? What types of services and infrastructure are available? On what basis? To whom? How successful are existing and past interactions between local groups and organizations and government agencies?

3. What is the stage of development of communities in the area? What are the characteristics of economic infrastructure (roads, bridges, markets, etc.)? What are the characteristics of existing patterns of local cooperation and beneficiary organization? Do these represent constraints that need to be overcome for improved production, productivity, and welfare? Do key factors such as markets, processing outlets, and other economic and social infrastructures support or constrain the proposed development initiatives?

4. Given population pressures and other factors, is the natural-resource base adequate to sustain increased production and productivity? Are there social, economic, political, or environmental processes (such as migration, rural industrialization, land-use conversion, deforestation, insurgencies) that influence pressure on the natural-resource base to directly support local employment, income, and food needs?

5. Who are the proposed beneficiaries for the development initiative planned for the area? What are the major characteristics of the project area that are likely to affect levels and forms of beneficiary involvement in the development initiative?

6. What is the actual or potential importance of the development initiative anticipated by the project in comparison with the other production, employment, and income-generating activities in the locality?

Describe the Problems and How People Currently Address Them

7. What are the problems and what are the consequences of the problems? How can problems be characterized in terms of levels and variations? What is the frequency of problems in relation to important agricultural and family life cycles? In relation to community resource-management practices? What are the locations of problems in relation to crop growth and utilization patterns, land-management practices, soil and land forms, and proximity to dwelling areas?

8. Which groups actually have these problems? What are the major ways that people assess these problems? What are the major ways, if at all, that people address these problems? How do these responses relate to other resource-management practices (such as weeding, plant and variety selection, and water control) and what, if any, extraordinary de-

mands do any of these responses make on land use or on family or community labor? When are responses initiated? How are the types and levels of responses phased? What are the durations? How are responses related to other resource-management functions?

Describe Potential Beneficiary Groups

9. What are the groups that will accept and support, carry out and benefit from the initiatives under the project? What are the major socioeconomic characteristics of each major beneficiary group? Are there disparities in wealth or social position among potential beneficiary groups that will affect the level, form, and conditions of their involvement and resource commitments, as well as the distribution of benefits? Are there special constraints facing or characterizing each of the beneficiary groups that need to be overcome to help ensure their involvement in the initiative and their participation in sharing anticipated benefits?

10. How do the priorities of potential beneficiary groups — in terms of resource allocation, sociocultural orientation, economic objectives — compare with those of the proposed development initiatives?

11. Are the behavioral changes required for implementing the development initiatives feasible from the viewpoints of the beneficiary groups, given local conditions and existing production systems? Do beneficiary groups understand what labor, financial, and material contributions may be needed for project implementation? Do they believe they can now (or in the future) make these contributions? Is there any past evidence that these groups are prepared or willing to make such commitments?

12. Will the project create any negative effects for any groups? What kinds of effects? How are these (likely to be) evaluated by these groups? By groups who are not negatively affected?

As noted throughout this paper, minimum understanding on all these points can be obtained through several channels, depending on specific situations, orientations, and purposes. However, for any agricultural technology management system, probably the two most important methodological guidelines that can be offered are these:

1. The more contact there is between farmer, farm, and the agricultural scientist, the better the chance that the scientist will work from a vision of the farmer's situation that leaps beyond stereotype and statistics.

2. It is equally important, however, to be realistic about how a specific agricultural technology management system can meet this guideline.

This means that while strategies for reducing stereotypical understanding by scientists can be evolutionary, these strategies must be broadly consistent with where the system is on Figure 1.

Contact between farmer, farm, and scientist can be obtained through extensive and frequent observation in the field by scientists, process documentation (Illo and Volante 1984), or rapid rural-appraisal exercises by agricultural technology management staff who have some regular way of reporting directly to scientists, group meetings in the field involving scientists (e.g., Coward, Koppel and Siy 1983), or the like. Especially in cases where scientists are going into the field, it is important to get away from the road, to talk to more than the male head of household, to actually stand in farm fields, and to get beyond the obligatory ceremonial events that visits by research station scientists often generate.

Conclusion

A final word: Monitoring and evaluation are tools, not products. When you have a closet full of tools, the important question is not, do I have any tools? The important first question is, which tools do I need? Agricultural technology management has to decide what it needs to know and what it is prepared to do with that information. Then it can choose the tools that can tell it about the things it needs to know, and perhaps a bit more. As what agricultural technology management needs to know changes, the tools employed to provide the needed information should also change. What is most important and what this paper has emphasized is that agricultural technology management has to think clearly about how it visualizes the impacts that are achieved and, within that understanding, what it needs to know.

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ASSESSING THE IMPACT OF RESEARCH ON IMPROVING THE QUALITY OF FOOD COMMODITIES

Laurian J. Unnevehr

Abstract

This paper shows how hedonic price measures can be estimated and used in evaluating the welfare gains from quality improvement in crop varieties. This methodology offers a relatively simple and inexpensive way to rank potential improvements in quality and to demonstrate the importance of such improvements to consumers. This paper presents a simple model of consumer demand for characteristics of goods and derives the equation for estimating hedonic prices. The limitations of assumptions underlying the model are discussed and solutions for common empirical problems in estimating hedonic prices are suggested. The impact of quality improvements on producer and consumer surplus is demonstrated. The paper concludes with an example of how this methodology has been used to evaluate returns to improvements in the quality of modern rice varieties.

Introduction

Agricultural research has focused primarily on increasing the food supply by raising yields. Often initial success in raising yield potential is achieved without incorporating other desirable characteristics in the food crop, such as eating quality. Once new varieties actually increase output and real prices start to fall, consumers can exercise greater choice and begin to pay higher premiums for eating quality. This induces producers to seek varieties with better eating quality and places pressure on agricultural research to incorporate better eating characteristics into high-yielding varieties.

Efforts to increase quality are sometimes criticized for diverting research resources from the more important task of increasing food supplies. How-

ever, food quality is important even to the very poorest consumers, and meeting food preferences can be an important part of fostering better nutrition (Shah 1983). Improving quality does not necessarily mean providing everyone with the best quality. Sometimes very simple changes in food characteristics can greatly increase palatability. Evaluating whether such changes are worthwhile is the subject of this paper.

When agricultural researchers seek to incorporate quality characteristics into new varieties, they need to have a way of measuring the importance of these quality characteristics to consumers. Such measures help guide research and demonstrate the potential payoffs to that research. This paper discusses how estimates of hedonic prices for quality characteristics can be used to evaluate the returns to research for quality. The first three sections of the paper present the model for estimating hedonic prices and discuss the limitations of the underlying assumptions and common estimation problems. The fourth section shows how hedonic price estimates can be used to measure welfare gains from improved quality under various assumptions. The paper concludes with an example of how this methodology has been used to evaluate the returns to quality improvement in modern varieties of rice.

Model of Demand for Characteristics

Several authors have proposed an alternative view of consumer demand in which consumers derive utility or satisfaction from the characteristics that goods possess, rather than the goods themselves (Becker 1965; Griliches 1971; Ladd and Suvannunt 1976; Lancaster 1966; Rosen 1974).1 For example, satisfaction is not obtained from food per se, but rather from the nutrients and flavor of the food. This model has been applied to consumer durables in order to estimate a quality-constant price index of inflation (see Griliches 1971 for examples).

In the area of food demand, a few authors have measured the value of food nutrients to consumers (Ladd and Suvannunt 1976; Morgan, Metzen and Johnson 1979). Studies of the value of food characteristics have also been conducted at the international agricultural research centers (Von Oppen and Jambunathan 1978; Unnevehr, Juliano and Perez 1985).

Hedonic price models all start by specifying the consumer utility function as a function of the quantity of goods consumed and the characteristics embodied in those goods. Different assumptions are made, however, concerning the

[1] Becker (1965) proposed a more comprehensive model in which goods are inputs into a household production function that produces the characteristics (i.e., a cooked meal with flavor and nutrients) that yield utility. In practice, it is difficult to applky this model because observations on household capital and labor inputs are rarely available.

relationship of the yield of characteristics to the quantity consumed and the separability of consumption decisions regarding quantity and characteristics.

Ladd and Suvannunt (1976) have developed a useful version of the hedonic price model that has assumptions suited to analyzing foods. In their model, the amount of a characteristic obtained from each good is fixed to the consumer (and variable to the producer), and the consumer determines the quantities of goods consumed. This seems reasonable for foods because the amount of nutrients or the flavor characteristics embodied in a food product cannot be determined by the consumer. Furthermore, hedonic prices in Ladd and Suvannunt's (1976) model are not required to be non-negative as they are in Lancaster's (1966) earlier model. It seems reasonable to assume in empirical work that some characteristics detract from quality and have negative utility.

The following is a slightly simplified summary of the Ladd and Suvannunt (1976) model. Let X_{oj} be the total amount of the jth product characteristic provided by consumption of all products, while X_{ij} is the amount of the jth characteristic provided by one unit of product i. Let q_i represent the quantity of product i consumed. Total consumption of each characteristic is a function of the q_is and the X_{ij}s (input-output coefficients of the characteristics):

$$X_{oj} = f(q_1, q_2, \ldots, q_n, X_{1j}, \ldots, X_{nj}) \tag{1}$$

for $j = 1,m$

The consumer's utility function is expressed as a function of the characteristics of the goods:

$$U = U(X_{o\,1}, X_{o\,2}, \ldots, X_{om}) \tag{2}$$

Because each X_{oj} is a function of the q_is and the X_{ij}s, then

$$U = U(q_1, q_2, \ldots, q_n, X_{11}, X_{12}, \ldots, X_{21}, \ldots, X_{nm}) \tag{3}$$

Consumers can only vary the q_is; the X_{ij}s are given to the consumer.

The consumer maximizes utility (equation 2) subject to the budget constraint:

$$\sum_{i=1}^{n} p_i q_i = E \tag{4}$$

where p_i is the market price for product i and E is total income (equal to total expenditures). The consumer selects values of q_i that maximize the Lagrangian

$$L = U(X_{o1}, X_{o2}, \ldots, X_{om}) - \lambda \sum_{i=1}^{n} p_i q_i - E \tag{5}$$

Because the X_{oj}s are functions of the q_is, the constrained maximum of U is

$$\frac{dL}{dq_i} = 0 = \sum_{j=1}^{m} \left(\frac{dU}{dX_{oj}}\right)\left(\frac{dX_{oj}}{dq_i}\right) - \lambda p_i \tag{6}$$

The marginal utility of income, λ, is equal to $\frac{dU}{dE}$. With this substitution and solved for p_i, equation 6 becomes

$$p_i = \sum_{j=1}^{m} \left(\frac{dX_{oj}}{dq_i}\right)\left(\frac{dU/dX_{oj}}{dU/dE}\right) \tag{7}$$

The marginal yield of the jth product characteristic by the ith product is dX_{oj}/dq_i. The marginal utility of the jth product characteristic is dU/dX_{oj}, and dU/dE is the marginal utility of income. Therefore, the ratio in brackets is the marginal rate of substitution between income and the jth product characteristic.

Because expenditure is assumed to equal income, the bracketed term is also the marginal implicit price of the jth characteristic. Equation 7 states that the product price paid by the consumer equals the sum of the marginal values of the product's characteristics. Each value is equal to the quantity of the characteristic obtained from a marginal unit of the product multiplied by the marginal implicit price of the characteristic.

Because the yield of most product characteristics is constant for each unit of product, $dX_{oj}/dq_i = X_{ij}$ = constant is assumed. Furthermore, the marginal implicit price is also assumed to be constant and is represented by P_{ij}. Therefore, equation 7 for a particular product, F, becomes

$$P_F = \sum_{j=1}^{m} X_{Fj} P_{Fj} \tag{8}$$

The addition of a random error term to equation 8 provides the familiar

equation used to estimate hedonic prices, P_{Fj}, from observations of characteristics, X_{Fj}, and market prices, P_F, of different qualities of good F.[2]

Market-Level Assumptions underlying the Model

Any model is based on simplifying assumptions, and the question for empirical applications is whether these assumptions are reasonably realistic. In estimating hedonic prices based on the above model, it is useful to examine whether the market under study conforms to the underlying assumptions of the model.

The model of consumer demand for goods characteristics assumes perfect competition in goods markets, which implies that perfect information is available to consumers about the quality characteristics of goods. Most food commodity markets tend to approximate the conditions of perfect competition because there are many buyers and sellers. When food standards are not regulated by a government agency, quality premiums should reflect the consumer's valuation of characteristics. However, consumers may not always be able to perceive quality characteristics when buying a good.

Certain eating-quality characteristics may only become apparent after food is taken home and cooked. In this case, consumers must either rely on proxy characteristics (such as a brand name) or on an established relationship with a retailer to obtain information about eating quality. For example, rice consumers in Thailand can easily identify the physical characteristics of rice but have no way of knowing the chemical characteristics that determine eating quality. For the latter, they rely on the place of origin of the rice as an indicator. In this way they are indirectly paying for the characteristics they want, and therefore price premiums for chemical characteristics should reflect consumer preferences.

Implicit in the assumption of competitive markets is the assumption that quality premiums are transmitted through the marketing chain. Many (if not most) food crops undergo some kind of processing between farm and consumer. The characteristics of the unprocessed commodity that produce preferred characteristics in the processed good must be known and measur-

[2] Note that this equation is linear. Lucas (1975) observed that the estimation equation derived from Lancaster's (1966) model is also linear, yet researchers frequently estimate hedonic price equations in a log-linear form. The log-linear functional form cannot be justified from theory but may be justified empirically by aggregation over consumers with different tastes, incomes, or nonhomothetic indifference maps.
There is also the issue of how to interpret the constant term. In Ladd and Suvannunt's (1976) original model, they define a unique characteristic for each good — one that is only found in that good. The price of this unique characteristic should be found in the constant. Alternatively, the constant can be interpreted as the value of the unspecified characteristics.

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able. Otherwise consumer preferences will not be transmitted back through the marketing chain and reflected in price premiums at the farm gate.[3]

Perhaps the most serious restriction of the model of consumer demand for goods characteristics is that it only models one side of the market. Prices observed in a marketplace reflect the forces of both supply and demand. Rosen (1974) has demonstrated that any estimated hedonic price represents both the marginal cost of producing a quality characteristic and the marginal utility of that characteristic to consumers. For example, a fancy variety costs more than ordinary varieties both because it tastes better and because it has higher costs of production. Rosen (1974) has suggested that this identification problem disappears when all consumers are identical but producers have different costs of production. Then, estimates from equation 8 identify consumer demand for quality.

Whether consumers have identical preferences for quality must be decided from prior information about the consumer population. Is it reasonable to assume that all consumers define quality in the same way? In other words, as incomes rise, will all consumers demand more of the same characteristics? If not, it may be desirable to estimate the hedonic price function separately for different segments of the population. This could be accomplished by collecting samples in markets frequented by particular income classes, or if resources are available, by household surveys of the purchases of particular income groups.[4]

Common Problems in Estimating Hedonic Prices

The first task for a researcher who wishes to estimate equation 8 is to choose X_{Fj}. The obvious starting point would be measures of quality that are already used in agricultural research for evaluating breeding material. However, a more rigorous approach would be to first conduct consumer taste panels and interviews about taste preferences. Such panels would ensure that all the relevant variables will be included in the estimation. In this approach, it is necessary to establish some correlation between consumer statements about quality and laboratory measures of quality. For example, if consumers prefer a sticky rice, are they choosing rice that has a low amylose content? If so, then amylose content is a good measure of quality in texture (Del Mundo and Juliano 1981).

[3] An alternative, related model for measuring the value of characteristics in a good that is an industrial input is found in Ladd and Martin (1976).

[4] Sometimes preferences may vary across different regions of a country. A national research program must then allocate scarce research resources to make quality improvements that will be valued by the largest possible portion of the population.

Not all the variables that determine quality are related to the genetic base of a food crop. Quality is determined by variety, growing environment, postharvest handling, and the interactions among these three factors. Identifying the role of genetics and other factors in food quality is an important step in the definition and interpretation of the measures of quality characteristics. For example, the percent of broken grains in milled rice is an important quality characteristic that would appear to be a function of postharvest processing. However, potential head-rice recovery in milling is an inherited trait and thus genetics also have an influence on this quality factor.

Quality characteristics are frequently highly correlated in a particular sample. Values of different characteristics tend to bunch together, because higher (or lower) quality varieties tend to have all the more (or less) desirable quality characteristics at once.[5] The resulting multicollinearity among variables inflates the standard errors of P_{Fj}. Therefore, it is difficult to estimate the individual contribution of each quality characteristic to total value. Although there are econometric techniques that will improve the reliability of the estimates, it is better to eliminate the multicollinearity problem if possible. More data could provide greater variation in combinations of characteristic values. It may also be the case that quality is actually viewed by consumers as a function of groups of characteristics, and individual characteristics have no value by themselves. If so, then it is more useful to define variables as combinations of characteristics.

The simplification of the above model to obtain equation 8 for estimation includes an assumption of constant marginal utility for each characteristic. This assumption may be unrealistic, particularly when there is wide variation in the observed range of values for a characteristic. In this case a nonlinear approximation (obtained, for example, by adding the squared value of a variable) may provide better estimates of hedonic prices.

Market prices vary for reasons other than quality. The whole schedule of price variation due to quality can shift up or down with changes in location or time of the year. In collecting market samples of different qualities of a food commodity, care should be taken to ensure that price variations are primarily due to quality. Usually this means limiting sampling to a particular time and location. However, if this is not possible, dummy variables can be added to the estimating equation to account for variation in prices across locations and sampling periods.

[5] Ironically, this bunching can occur even when there is no relationship among characteristics across different breeding lines. That is, it is technically possible to breed a variety with any combination of characteristics, yet in practice, only a few combinations are common in varieties planted by farmers.

Measurement of the Welfare Gains from Improved Quality

Agricultural research can alter the amounts of different characteristics available to consumers in each unit of a food commodity For example, plant breeders can alter the chemical characteristics of rice varieties and thereby change the cooked texture of milled rice. When research alters the X_{Fj}s in a food commodity, the demand for that commodity will shift because the utility gained from consumption increases. This demand shift will increase consumer surplus. Whether the price of the commodity and producer surplus also change will depend on the cost of production of the new higher quality variety. This section outlines the theory behind the measurement of changes in producer and consumer surplus following a change in a good's characteristics.

Ladd and Suvannunt (1976) have shown that the relationship of quantity demanded of good u to changes in characteristic v are

$$\frac{dq_u}{dX_{uv}} = \left[\left(\frac{-\,{}^{1}\!/_{dU}}{dE}\right)\left(\frac{dU}{dX_{uv}}\right)\right]\left(\frac{dq_u}{dP_u}\right)^{*} \tag{9}$$

where $\left(\frac{dq_u}{dP_u}\right)^{*}$ is the income-compensated, own-price substitution effect from the Slutsky equation. It is assumed that the change in X_{uv} does not alter any of the other marginal utilities of the characteristics. From equations 7 and 8,

$$\left[\left(\frac{-\,{}^{1}\!/_{dU}}{dE}\right)\left(\frac{dU}{dX_{uv}}\right)\right] = -P_{uv}$$

As the income-compensated, own-price substitution term is always negative, an increase in a positively valued characteristic will increase the quantity demanded of the good.

The change in quantity demanded is represented by a shift to the right in the demand curve (Figure 1). This increase in quantity demanded is equivalent to an increase in consumer utility obtained from each unit of the good. From equation 8, this increase is equal to

$$G = (X^{*}_{uv} - X_{uv})\,P_{uv} \tag{10}$$

where

G = the consumer surplus gain per unit of good u consumed
P_{uv} = the hedonic price of characteristic v
X^*_{uv} = the new value of characteristic v obtained from one unit of u
X_{uv} = the old value of characteristic u obtained from v[6]

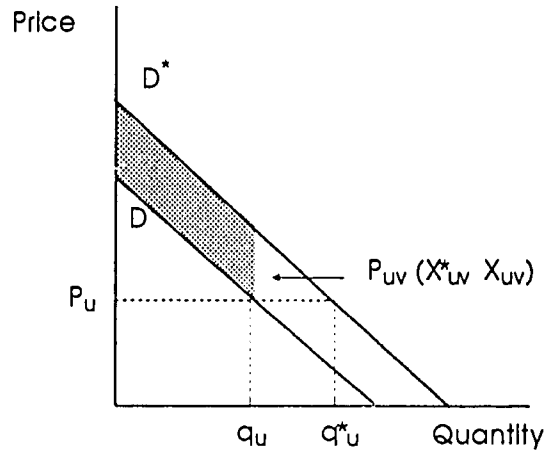

Figure 1. Gains in consumer surplus from improvements in quality with infinitely elastic supply

It is assumed that P_{uv} does not vary with the change in X_{uv}. The new quantity demanded, q^*_u, is given by the following:[7]

$$q^*_u = q_u \left[1 - \frac{G}{P_u} \varepsilon_d\right] \tag{11}$$

where ε_d is the income-compensated, own-price elasticity of demand. In order to estimate q^*_u, it is necessary to have some estimate of the income-compensated, own-price elasticity of demand for the food commodity in question. Fortunately, in most countries existing consumer-demand studies can provide such estimates for the major food crops.[8]

[6] If more that one characteristic changes, then G is equal to the sum of the changes in characteristics times their implicit value.

[7] The demand function can be written as

$$P_d = P_u\left(1 - \frac{1}{\varepsilon_d}\right) + \left(\frac{P_u}{q_u \varepsilon_d}\right) q_d \tag{11a}$$

The new demand function after the quality change is

$$P^*_d = P_u\left(1 - \frac{1}{\varepsilon_d}\right) + G + \left(\frac{P_u}{q_u \varepsilon_d}\right) q^*_d \tag{11b}$$

Solving equation 11b for the new equilibrium quantity yields equation 11 in the text.

[8] The income-compensated, own-price elasticity of demand can be calculated from estimates of the own-price elasticity, the income elasticity, and the budget share, using the Slutsky equation.

The size of the total change in consumer surplus depends on whether the price of good u, P_u, changes following the change in quality. This in turn depends on the cost of production of the new higher quality variety and the elasticity of supply. In the simplest case, the new higher quality variety would have the same cost of production as the most common older varieties, and supply would be infinitely elastic over the range of the increase in quantity demanded. This latter assumption would not be unrealistic for fairly small shifts in quantity demanded. Under these assumptions, P_u would remain unchanged, there is no change in producer surplus, and the consumer surplus gain is the shaded area in Figure 1. This area is estimated by the following:

$$CS = q_u G + \frac{1}{2}[(q^*_u - q_u)\, G] \tag{12}$$

Even if the new, higher quality variety has the same costs of production as existing ordinary varieties, the increase in quantity demanded may be large enough that increased supply can only be provided at higher cost. In this case, supply is not infinitely elastic over the range of the increase in quantity demanded, and the price of good u will increase after the quality change. This situation is illustrated in Figure 2. Consumers gain the area *ebfg*, producers gain the area *abcd* (of which *afcd* is a transfer from consumers), and society's net gain is *ebcg*.

In order to estimate the changes in consumer and producer surplus, it is first necessary to estimate the new equilibrium P^*_u and q^*_u. In this case, some estimate of the elasticity of supply is needed. Then the new equilibrium can

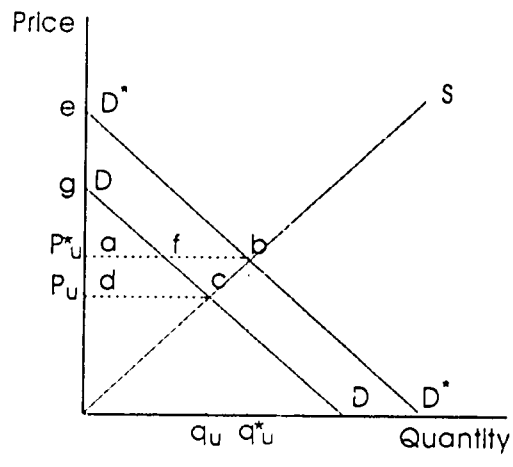

Figure 2. Changes in producer and consumer surplus after improvements in quality with less than infinitely elastic supply

be calculated from the following:[9]

$$q^*_u = q_u + \left[\frac{G\left(\frac{q_u}{P_u}\right)}{\frac{1}{\varepsilon_s} - \frac{1}{\varepsilon_d}}\right] \tag{13}$$

$$P^*_u = Pu\left(\frac{1-1}{\varepsilon_s}\right) + \frac{P_u}{\varepsilon_s} + \left[\frac{\frac{G}{\varepsilon_s}}{\frac{1}{\varepsilon_s} - \frac{1}{\varepsilon_d}}\right] \tag{14}$$

where ε_s is the elasticity of supply. The net social gain is given by

$$NS = q_u G + \frac{1}{2}\left[G\left(q^*_u - q_u\right)\right] \tag{15}$$

Although this contains the same terms as equation 12, the net social gain in this case will be smaller because q^*_u is smaller.

It may be of interest to calculate the gains to consumers and producers separately in order to see the income-distribution effects of the change (Bale 1979). The following equations give the changes in consumer and producer surplus:

$$CS = q_u G \tag{16}$$

$$PS = q_u\left(P^*_u - P_u\right) + \frac{1}{2}\left[\left(q^*_u - q_u\right)\left(P^*_u - P_u\right)\right] \tag{17}$$

If producers are generally poorer than consumers, then the transfer from consumers to producers will improve the distribution of income. If purchasing consumers are poorer than producers, then a quality change that results in a price increase will cause a deterioration in the distribution of income.

The net social gain can be estimated on the basis of production in one year, and presumably this gain will reoccur for several years in the future. The

[9] The supply functions can be written as

$$P_s = P_u\left(1 - \frac{1}{\varepsilon_s}\right) + \left(\frac{P_u}{Q_u \varepsilon_s}\right) q_s \tag{13a}$$

The new demand function after the quality change is still equation 11b. Setting equation 11b equal to 13a and solving for the new equilibrium quantity yields equation 13 in the text. Substituting the right side of equation 13 for q_s in equation 13a yields equation 14 in the text. See Norton and Davis (1981) for a review of equations used to calculate consumer and producer surplus changes.

present value of the net social gain in future years can be compared with the present value of research costs to develop the new variety in order to estimate the returns to research on quality improvement.

The methodology presented in this section relies on some simplifying assumptions. First, supply and demand curves are assumed to be linear over the portions relevant to the demand shift. Hertford and Schmitz (1977) have argued that the difference in surplus estimates between linear and nonlinear models is small for the percentage changes usually considered in returns to research studies, so this simplification seems reasonable.

The second simplification is that international trade is not explicitly incorporated into the model of supply and demand. In an open economy, exports or imports adjust so that price will not vary with the shift in the demand curve. Domestic consumers then gain from the increase in quality of domestically produced food. Equation 12 provides estimates of the consumer surplus gain from consumption of domestic production. Welfare gains will probably be limited to the domestic market because the value and even the definition of quality frequently differ between domestic and world markets. On the other hand, if the quality improvements are valued on the world market and the commodity is exported, consumers outside the country will benefit. Domestic producers of the commodity will benefit only if the increase in quality allows them to capture a greater share of the world market.

Finally, this discussion does not include the impact of quality improvement in a variety with higher costs of production than current ordinary varieties. This type of improvement would provide benefits only to a limited group of producers who could grow the variety and to better-off consumers who could afford to buy it. This would not serve the primary goal of agricultural research, which is to increase food supplies and the welfare of low-income consumers and producers. Therefore, this case is not considered here.

An Example of Returns to the Improvement of the Quality of Rice

Hedonic prices of rice characteristics were estimated for samples of rice from three Southeast Asian countries at the International Rice Research Institute (IRRI).[10] One of the striking findings was the universal and strongly significant preference for better milling quality, i.e., fewer broken grains of rice and better polish. An increase of 1% in the proportion of broken grains in rice reduced the price of rice by 0.12 cents/kg in the Philippines and 0.18 cents/kg in Indonesia.

[10] See Unnevehr, Juliano and Perez (1985) and Unnevehr (1986) for details of the study.

Potential head-rice recovery in milling is an inherited trait. The earliest modern varieties (MVs) of rice, IR5 and IR8, had potential head-rice recovery of only 36% to 40% of paddy. By 1970, these early MVs had been adopted on 50% of the area planted to rice in the Philippines and on 25% of that in Indonesia (Herdt and Capule 1983; Salmon 1984). IR20, a new MV with potential head-rice recovery of more than 60%, was introduced in 1970 and rapidly replaced the earlier MVs in farmers' fields.

The increase of 38% in potential head-rice recovery with the introduction of IR20 had a value to consumers of 4.56 cents/kg in the Philippines and 6.84 cents/kg in Indonesia (Table 1). If the own-price elasticity of rice is 1.16 in Indonesia (Timmer and Alderman 1979) and 0.67 in the Philippines (Bouis 1982), then this quality improvement should have led to an 8% increase in consumption in the Philippines and a 14% increase in Indonesia. This increase in demand could be supplied by an increase in adoption of higher-yielding MVs, which in fact occurred after the introduction of IR20. Therefore, supply was assumed to be infinitely elastic over the range of the projected increase in demand. The total annual gain in consumer surplus was $73 million in the Philippines and $224 million in Indonesia (Table 1).

The cost of developing better head-rice recovery is taken to be 15% of IRRI's budget from 1962 (when the Institute opened) to 1969 (when IR20 was released). IRRI plant breeders estimate that 15% of the program effort was devoted to quality, and as other programs support plant breeding, 15% of the total budget is taken as a conservative estimate of costs.

The future value of the gain in consumer surplus was compared to the past value of research costs. The improvement in head-rice recovery had a

Table 1. Gains in Welfare from the Introduction of Modern Rice Varieties with Better Head-Rice Recovery

	Philippines	Indonesia
P_{uv} (X^*_{uv} X_{uv}) (c/kg)[a]	4.56	6.84
q_u (000 MT rice)[b]	1532	3059
q^*_u (000 MT rice)[c]	1655	3487
CS (million $)[d]	73	224

[a] Head-rice recovery assumed to improve 38%. Each reduction of 1% in broken grains increases the price by 0.12 cents/kg in the Philippines and by 0.18 cents/kg in Indonesia.
[b] Consumption of modern varieties of rice is 50% of average 1967-1971 rice production in the Philippines and 25% of that in Indonesia.
[c] Estimated from equation 11, with own-price elasticity of rice assumed to be 1.16 in Indonesia (Timmer and Alderman 1979) and 0.67 in the Philippines (Bouis 1982).
[d] This is estimated from equation 12.

benefit-cost ratio of 49 (using a 12% discount rate) and an internal rate of return of 61%.[11] This return is substantial, although not as large as past returns to improvements in rice yields that have been as high as 84% to 87% (Evenson and Flores 1978; Scobie and Posada 1976). These large returns to quality improvement suggest that there is underinvestment in research to improve the quality of agricultural commodities, in addition to the widespread underinvestment in research to increase yields suggested by Akino and Hayami (1975).

Concluding Comments

This paper has outlined a methodology for measuring the returns to research that come from improving the quality of food commodities. While agricultural research focuses on raising yield potential, many programs already evaluate the quality characteristics of breeding material. The methodology outlined here would enable these programs to test the importance of quality measures and to estimate the potential returns to improving quality with few additional research resources. The hedonic or implicit prices of quality characteristics are relatively easy to estimate from market samples. If the laboratory equipment is in place to screen breeding lines for quality, then it is easy to also measure the quality characteristics of market samples. These characteristic measures can then be regressed on observations of market prices with a microcomputer statistical package.

Interpreting the estimates of hedonic prices requires knowledge of the commodity market and consumer preferences, which must be provided by economists, cereal chemists, and other scientists in the quality program. If the estimates are reasonable and significant, then they provide a measure of the value of different quality characteristics to consumers. These values yield estimates of the returns to research for improving quality and can be used to rank the importance of potential quality improvements in setting research priorities.

More important, the returns to quality improvements can be used to demonstrate the usefulness of research to improve quality. Most agricultural research seeks to increase the food supply in order to benefit consumers and producers who retain their crop for home consumption. If, in addition to increasing food supply, agricultural research can also provide varieties of better quality that have the same or lower production costs as current varieties, then the welfare of all consumers is enhanced.

[11] Full adoption of IR20 (or later varieties with equivalent milling quality) was assumed to be complete five years after introduction. Hence, consumer benefits start five years after the improvement and last for 50 years.

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THE EXCESS BURDEN OF TAXATION AND PUBLIC AGRICULTURAL RESEARCH

Dana G. Dalrymple

Abstract

It has recently been suggested that studies of rates of return to public agricultural research should be discounted by the amount of the deadweight loss (or excess burden) associated with the use of tax funds. Although the concept of excess burden is deeply rooted in the history of economic thought and variants are utilized in some areas of policy and trade, it is not widely or well known. This paper outlines the main steps in the development of the concept, examines trends in the use of public funds for agricultural research in the United States from 1915 to 1984, and discusses the relevance and utilization of the concept in this context. The general notion of discounting appears to be theoretically justified, but is difficult to implement because of the difficulty in deriving appropriate measures of excess burden.

To tax and to please, no more than to
love and be wise, is not given to men.

Edmund Burke, 1774

Introduction

In a recent article about investment in agricultural research in the United States, Fox (1985) introduced the concept of deadweight loss (also known as excess burden, welfare cost, or social loss). This loss allegedly arises from distortions in factor and product markets which occur when government expenditures are financed by traditional tax procedures.

Fox went on to suggest that these losses ". . . need to be charged against public expenditures to obtain the true opportunity cost of public programs" (1985: 809). Some recent estimates of such losses are then used to indicate

the impact on estimates of internal rate of return. Fox focuses on marginal rather than average losses on the basis that the share of public expenditures spent on agricultural research is small.

There is something old and something new in Fox's paper. The general notion of welfare costs and the term *deadweight loss* have been used quite widely in agricultural policy and trade analyses (Currie, Murphy, and Schmitz 1971; Gardner 1986; Runge and Meyers 1985). But Fox is the first, to my knowledge, to apply them to the evaluation of agricultural research supported by general tax funds.

This is a significant step and merits further study. Yet other economists may find that it is a difficult subject to track down. Neither Fox nor the references he cites provide any particular background. Moreover, the subject is not mentioned in many general economics texts. It is more readily found, and then with some limitations, in welfare economics and public finance texts.[1]

This relative anonymity is puzzling. Excess burden would appear to be an important concept of broad relevance. It could also be quite timely in view of current interest in tax policies and constraints on government spending.

Taxes have, of course, long provided a major portion of the funding for agricultural research.

It would seem useful to know more about the concept and how it relates to agricultural research. This paper, therefore, attempts to provide a relatively balanced introduction. Three steps are involved:

1. a review of the literature pertaining to the concept of excess burden and its measurement;

2. an examination of data on the past level of public expenditure for agricultural research in the United State;

3. a discussion of the application of the concept.

Although the focus is on agricultural research in the United States, the issues raised could apply to a wider range of public activities and to other countries.

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[1] The fullest treatment found in general economics texts is provided by Fischer and Dornbusch (1983). In the case of welfare economics texts reviewed, coverage was usually scattered and highly theoretical. Just, Heuth, and Schmitz (1982), however, provide a brief but clear introduction. In the case of public finance texts, particularly good coverage is provided in Musgrave and Musgrave (1984), Rosen (1985), and Stiglitz (1986). Most texts provide no historical background, focus on partial equilibrium effects, and give little attention to social benefits from government expenses.

The Concept of Excess Burden

While some taxpayers would be willing to accept the notion of excess burden sight unseen, it is not intuitively obvious to many. And it is difficult to introduce briefly and convincingly in words. Here an evolutionary approach is utilized which focuses on the development on the concept, its measurement, and a few associated problems. Fairly heavy reliance is placed on some simple diagrams.

Origin and Early Development

Although the concept might appear to be of recent and conservative origin, this is hardly the case. Its roots run deep into the history of classical economics. It is part and parcel of the theory of economic or consumer surplus. Five eminent economists were involved in its development.

The concept was, as far as can be told, first suggested by the French engineer and economist Dupuit (1957). In a note to his classic article, *On the Measurement of the Utility of Public Works*, published in 1844, Dupuit analyzed the welfare effects of the imposition of an excise tax, as shown in Figure 1.[2] He stated that "A small tax of *pp'* will yield the rectangle *pp'n'q* and the

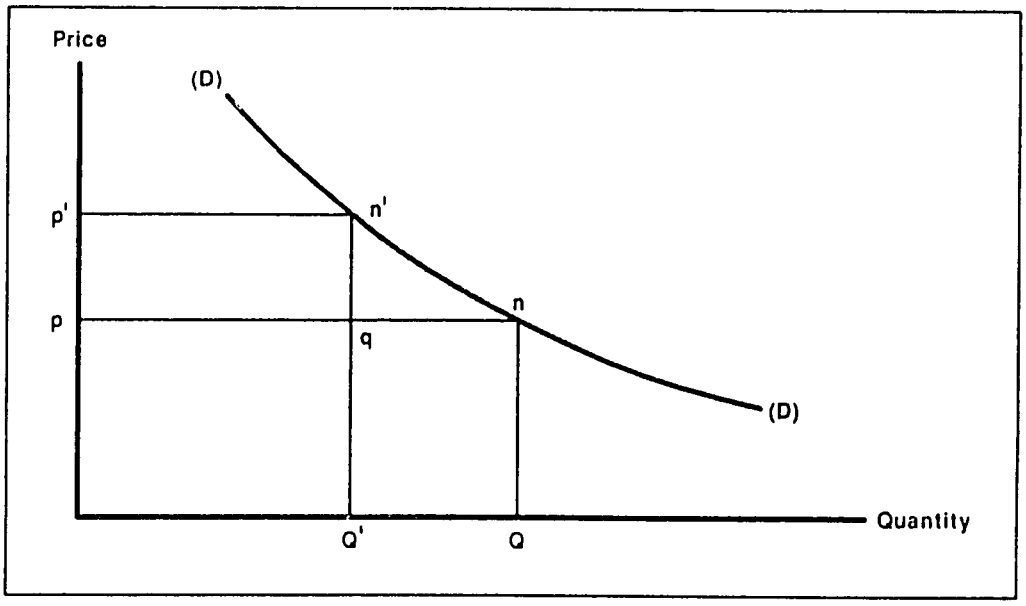

Figure 1. Dupuit's analysis of the effects of a tax, 1844

[2] Actually Dupuit's (1957) original presentation had price on the horizontal axis and quantity on the vertical axis. They have been switched here to conform with current practice. The diagram is similar to one presented by Currie, Murphy, and Schmitz (1971: 766) but retains Dupuit's original notation.

utility lost both to the taxpayers and the fisc [treasury] is the small triangle *nqn* " (1957: 54; italics added).

Marshall (1959) took up the same issue in his classic book, first published in 1890. He differentiated between constant, diminishing, and increasing returns. The first two are of principal interest here.

- *Constant returns.* His analysis basically followed Dupuit's, and his diagram was essentially the same (except that the horizontal price lines were treated as supply "curves"). Marshall noted that the loss of consumers' surplus is smallest for those commodities that have the most inelastic demand elasticities.

- *Diminishing returns.* This situation is shown on a now-familiar diagram (Figure 2). The tax is levied at the rate *aE* on each unit, with the result that output is reduced from *OH* (or *CA*) to *Oh* (or *CK*). In this case, Marshall stated that the gross receipts, *cFEa*, are greater than the loss of consumers' surplus, *cCAa*. He was not, however, very explicit about changes in producers' surplus and overall social gain or loss.[3]

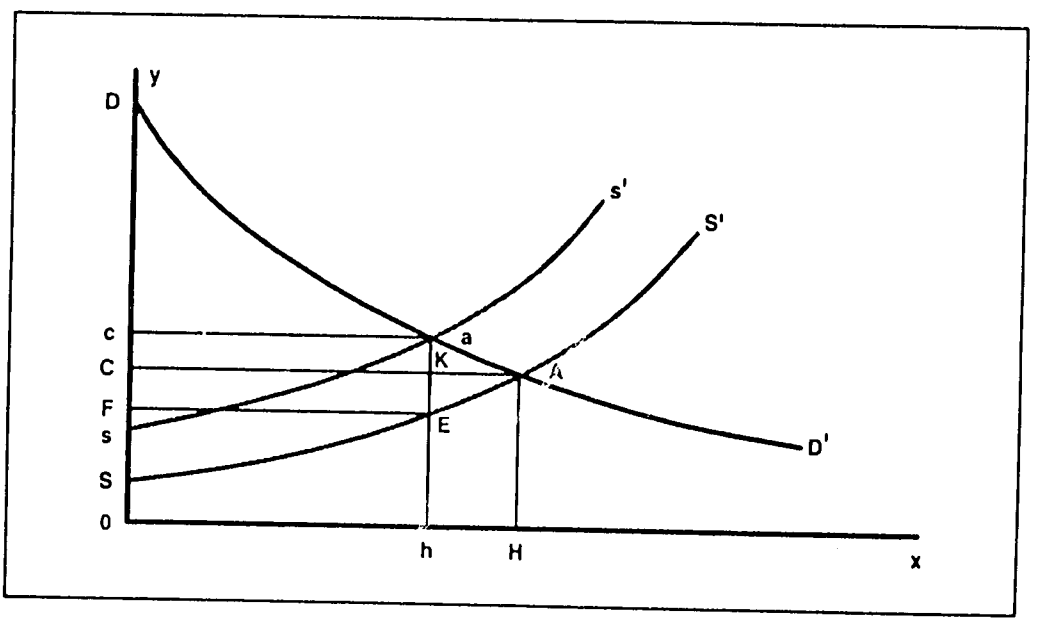

Figure 2. Marshall's analysis of the effects of a tax, diminishing returns, 1890 (or later)

[3] This was in part because Marshall (1959) did not refer to producers' surplus in the text (and did not discuss it in diagrammatic form until Appendix H, p. 668, and then in a different context), nor did he refer to the social cost.

A fuller discussion was provided by Hotelling in 1938. He used Marshall's basic diagram, but changed the notation (Figure 3). His comments on the effect of a tax may be summarized as shown in Table 1 (using his terminology).

The difference between *SDB* and *SNLD* is the triangular area, *NBL*, the "net social loss." Hotelling went on to develop an algebraic expression of the approximate loss. He also referred to the loss accruing from shifting from a system of income taxes to excise taxes (or from sales at marginal cost) as a "dead loss," and reviewed tax systems for minimizing this loss. In a subsequent exchange of views with Ragnar Frish he emphasized that he was referring to the ". . . social loss from a system of excise taxes in contrast to more efficient types. . ." (Hotelling 1939: 154).

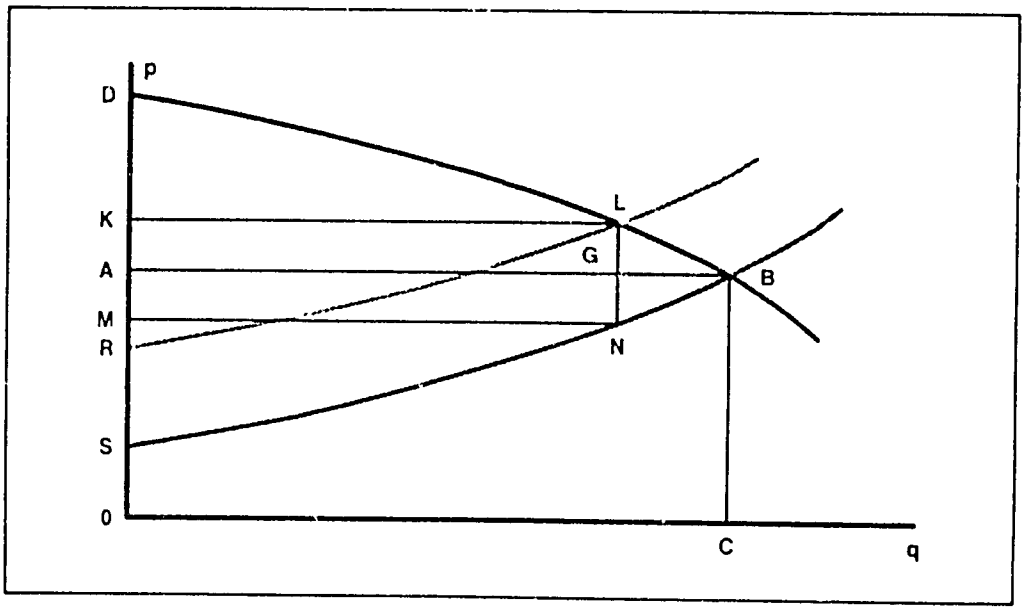

Figure 3. Hotelling's presentation of the effects of a tax, 1938

Table 1. Summary of Hotelling's Comments on the Effect of a Tax

	Original Equilibrium	After-Tax Equilibrium
Consumers' surplus	*ABD*	*KLD*
Producers' surplus	*SBA*	*RLK* (= *SNM*)
Government revenue		*MNLK*
Total net benefit	*SDB*	*SNLD*

In 1941, Hicks took up the question of social loss in a more general paper about consumers' surplus. He noted that the triangle results from a loss in both consumers' and producers' surplus and is only an approximate measure because it assumes a constant marginal utility of money. "It measures the social loss involved in producing a nonoptimum instead of an optimum amount" (1941: 114). He referred to it as the "social loss" and said that it depends partly on the gap between price and marginal cost and partly on the effect of that gap on output. It can be measured as $\frac{1}{2}x$, where the tax per unit is $\frac{1}{2}$ and x is the reduction in output.

There the matter largely rested, aside from some references in highly theoretical papers, until the early 1960s. In 1964, Harberger (1964b: 45-46) expanded the area of analysis from the usual excise or sales tax case to the effect of income taxes on labor income. This is illustrated in diagrammatic form in Figure 4, where *LL* is the supply curve of labor, *W* is the prevailing wage, *rw* (= *AC*) is the amount of tax per unit of labor, and *DA* is the net income per unit of labor. The reduction in the amount of labor performed as a consequence of an income tax at the rate *r* is *BC*. The overall reduction in gross money income to the worker is *DEBC*, and the worker will have gained leisure value of *DEBA*. This leaves the net welfare cost of the tax as the triangle *ABC*.[4]

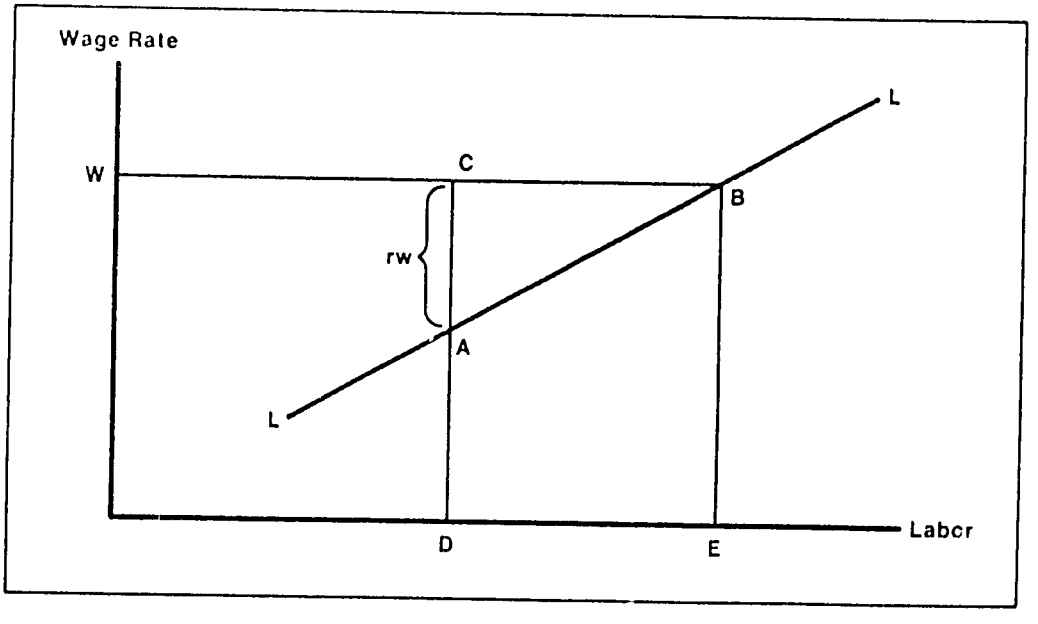

Figure 4. Harberger's diagram for evaluating the effects of an income tax on labor income, 1964

[4] The diagrams used in this section have moved, with variations, into common use in textbooks. Reference is, however, now usually made to compensated demand curves. Excess burden may also be analyzed in terms of indifference curves, but they are not a useful device for measurement.

Measurement of Excess Burden

As so often occurs, it proved easier to propose the concept than to measure it. Through 1964 little happened in terms of deriving specific estimates. In that year, Harberger (1964a: 59, 60) commented that the economics profession had not given the concept the attention it deserved, saying that it was ". . . the province of only a handful of economists rather than at least the occasional hobby of a much larger group." He acknowledged three possible reasons for its "apparent unpopularity": (1) the difficulty of obtaining numerical values for key elasticity variables, (2) the difficulty in taking account of other distortions, and (3) a more general suspicion of the theory of consumer surplus.

Partial Equilibrium Approaches

Harberger went on to explore a variety of possible partial equilibrium ways to measure the deadweight loss, which he called "welfare cost of a tax system" elsewhere (1964b). In the process, he built on previous work and developed a basic formula for measuring welfare change; several variants were also explored.[5]

One of the first, and perhaps the most widely cited, applications of the Harberger formula was reported by Browning in 1976. He calculated that the marginal excess burden for taxes on labor income in the United States was from 9 to 16 cents on the dollar in 1974. Numerous other studies followed.[6] The partial equilibrium approach, however, had several limitations. As noted by Stuart (1984), these were the following: (1) it is exact only in the neighborhood of an undistorted equilibrium, (2) the Harberger formula is conceptionally inadequate for measuring marginal excess burden, and (3) it does not consider the effect of taxation on the tax base.

Stuart (1984) went on to note under point 2 that while the formula correctly measures the cost of failing to use lump-sum taxation, this is not the alternative forgone in raising an additional dollar of tax revenue.

To calculate the welfare cost of raising an additional dollar of revenue, one wishes to compare changes in utility and revenue as the economy moves

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[5] The formula is provided in Harberger (1964a: 61). He notes that the basic expression ". . . pops up in one form or another all through the literature on the measurement of welfare costs. . ." (1964a: 62). He provides a more general formula for measuring welfare change in his 1971 paper; it includes a policy variable, which in this case is a tax (1971: 789).

[6] Many are summarized in St-Hilaire and Whalley (1982: 44-47). Most of these are based on a comparison with lump-sum taxation, which essentially doesn't exist (one example is a poll tax). Hence, it is not a particularly realistic base, although it does represent the "optimum" in terms of minimal distortion (and a minimum in equity).

from an equilibrium before a tax increase to one after the tax increase (Stuart 1984: 352).

Moreover, since the equilibrium level of tax revenue generally depends on the way in which the government spends the revenue, the value of the marginal excess burden cannot itself be independent of the type of marginal spending (Stuart 1984: 353).

Hansson and Stuart (1984: 332) also subsequently noted that:

> . . . the full equilibrium response of the economy to a balanced budget increase in public spending depends in part on how the marginal spending influences private demands and supplies. Such influences . . . are referred to as "expenditure effects" . . .[7]

General Equilibrium Approaches

A broader approach was needed. This was provided by general equilibrium models. Four of particular significance will be noted here. The first two are cited by Fox (1985).

Stuart (1984) calculated the marginal excess burden (*MEB*) from taxes on labor income in the United States. He limited government expenditures to only two items: (1) redistribution to the household, and (2) government consumption. The former was treated as a perfect substitute for private consumption of taxed-sector output. The latter is assumed to have no influence on the marginal rate of substitution between the outputs of the two sectors. His "benchmark" *MEB* figure was 20.7 cents per dollar. (Variants ranged higher and lower, but Fox cited only the upper range.) When the model was rerun to direct all the tax revenue into government consumption, the *MEB* dropped to 7.2 cents, or by two-thirds. Stuart noted that the size of this reduction ". . . provides strong confirmation that the ultimate use of public funds matters" (1984: 359).

A subsequent general equilibrium study by Ballard, Shoven, and Whalley (1985) covered all taxes. They assumed that the government uses its revenues (1) to provide transfer payments to the household sector, and (2) to make exhaustive expenditures that do not directly affect consumer utility or the structure of production. Like Stuart's, their model does not allow for complementarity between public goods and private goods (a relationship previously suggested by Atkinson and Stern 1974). They note that if this were done, the *MEB* might be reduced. Their estimates varied, according to

[7] Expenditure effects had previously been noted by Lindbeck (1982).

elasticity assumptions, from 17 to 56 cents; they expressed most confidence in a mid-range figure of 33 cents (Ballard, Shoven, and Whalley 1985: 135).

The same two variables were also studied by Hansson and Stuart (1984) using Swedish data for 1979. They found that the marginal cost of public funds that were redistributed to taxpayers was nearly 36% higher than for expenditures that had no influence on private behavior. Moreover, the marginal cost ". . . for a given marginal fiscal program can be less than one or infinite depending on the specific characteristics of the program." The low-end result shows that ". . . tax increases can in some instances be anti-distortionary" (1984: 333). The authors also found that the cost of public funds was influenced by the specific tax instruments used and the initial levels of the tax rates.

A more flexible approach was taken by Hansson (1985) in another study when he added a third category of government expenditures: infrastructure that increases productivity in the taxed sector (*INF*). These expenditures give a proportional upward shift in the production function in the private sector. On the basis of Swedish data for 1979, the marginal cost of the infrastructure expenditures was close to zero. In the author's words, "This implies that a marginal benefit of unity is sufficient to rationalize this type of expenditure" (1985: 129).

Hansson (1985) did not define the components of *INF*, but certainly they would include technological change. Harberger briefly considered this possibility in 1971. He stated that "when technological advance occurs, the resources thus freed are enabled to increase total welfare" (1971: 793). In diagrammatic terms (Figure 5), a reduction in unit costs from *OA* to *OB* would produce a benefit of *ABCD* in the absence of distortions.[8]

A Rejoinder

Browning, noted earlier as having made the first calculations of MEB using a partial equilibrium approach (1976), recently returned to the subject in the light of subsequent work with general equilibrium models (1987). He noted the higher estimates derived from these models and the assumption that they capture some essential elements that are missing in the partial equilibrium approach. He does not believe that this is the case. Once a correction is made in the partial equilibrium model, which raises the estimate of *MEB*, virtually all the differences in results can be traced to different assumptions about key parameter values. His preferred revised estimates of the *MEB* range from 32% to 47%, depending on what assumption is made about the extent to which taxpayers benefit from marginal government

[8] Harberger (1971: 793-794) also discusses the impact in algebraic terms.

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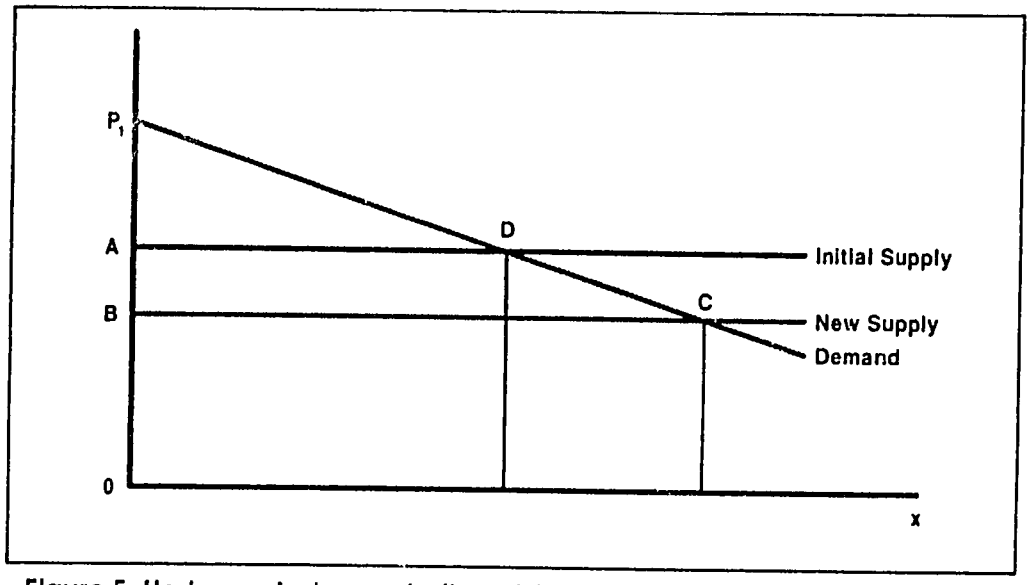

Figure 5. Harberger's demonstration of the effect of technological advance, 1971

spending. While he acknowledges that (other things being equal) the results from the general equilibrium model are to be preferred to those of the partial equilibrium model, the latter approach has two important advantages: (1) it is more easily understood, and (2) it is easy for other investigators to perform sensitivity analysis.

Some Points of Interpretation

Clearly, the concept and measurement of excess burden has undergone some changes over time. The precise terminology tends to vary with the author, as reflected here. Along with this have gone subtle and not so subtle changes in meaning. Some economists take a broad view; others, a narrower view.

This was nicely illustrated in an exchange between Frisch and Hotelling in 1939. Frisch, in commenting on Hotelling's paper (Hotelling 1938), said that "The relevant question is, of course, what the government does with the money," and "If this is done, there will not be any 'net social loss,' but possibly a great gain" (1939: 150). (He was perhaps optimistic.) In response, Hotelling stated that his statistical expression of the social loss applied to ". . . a system of excise taxes in contrast to more efficient types, regardless of what the government does with the money" (1939: 154).

In discussions such as this, one person may be thinking of what could be called *gross* excess burden and the other of *net* excess burden. The immediate effect of a tax might be called the gross burden and this is the same no matter what use is made of the taxes. The longer-term effect, taking use of tax funds

into account, might be called the net excess burden. The net figure may be quite different from the gross figure. It is of course essential to know the difference in making use of estimates.

Another aspect that should be kept in mind is the existence of some skepticism about the concept and its measurement, both by economists and by the public. Some economists, such as Cochrane (1980), do not subscribe to the basic theory of consumers' surplus and have indicated that they think it of greater theoretical interest than of practical value.[9] When Harberger presented the welfare cost idea in 1963 to a tax conference, the response was mixed; most of those who attended evidently agreed but some did not. The conference summary noted that ". . . welfare aspects of taxation are not settled doctrine" (Chase 1964: 297-298). The concept of excess burden met somewhat the same reaction at another tax conference in 1979 (Aaron and Pechman 1981: 24).

Public Appropriations for Agricultural Research in the United States

So far we have largely dealt with general conceptual matters. We now turn to more specific and empirical issues relating to public agricultural research. This will be done by examining long-term data on public appropriations in the United States. The review provides an introduction to available data and trends at the national level and sets the stage for considering Fox's statement that "Since the share of public expenditure that is spent on agricultural research is small, the marginal social opportunity cost (rather than the average) is the relevant measure" (1985: 809, footnote 3).

We will be concerned here with total public appropriations at the federal and state level.[10] These data are then normalized on several different bases. Four steps are involved. The computations themselves are quite ordinary, but have not, to my knowledge, heretofore been taken at the national level.[11]

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[9] Considerable literature exists on the limitations of theoretical welfare economics (see Runge and Meyers 1985).

[10] Funds from other sources are excluded. Hence, the data do not include fees, sales, miscellaneous sources, and special funds. In recent years, the totals include some new federal appropriations for forestry and veterinary research, but these figures are quite small compared to the total (the same situation may occur in some of the state data). The appropriations are for domestic programs only: foreign aid funds for international agricultural research activities, some of which are of benefit to the United States, are excluded.

[11] In the past, expenditure data have generally been disaggregated and normalized at the state or commodity level. State data have, for instance, been normalized on the basis of state population, farm income, number of farms, etc., and used to facilitate comparisons between states (see Dalrymple 1962 for an early example). Commodity data, both federal and state, have been normalized on the basis of value of production, value added, etc. (see Ruttan 1983 for a recent example).

The interrelations between data and theory will be considered in the final section of this paper.

The Time Period and the System

Data have been assembled for public appropriations for the 70- year period from 1915 to 1984. The earlier date was set by the ready availability of data, but it is also an appropriate starting point in terms of the emergence of the federal-state research system. Federal research was quite modest until the arrival of James Wilson as Secretary of Agriculture in 1897; by the end of his term in 1913, the Department of Agriculture had been built into a significant research organization. Most states established research programs somewhat earlier, but were largely supported by federal funds under the Hatch Act, passed in 1887. About 55% of their funding from 1889 to 1915 came from federal funds. After 1915, nonfederal funds, primarily state appropriations, became a much more important source of funding and federal funding subsided to the range of 19% to 30%.[12]

Total Appropriations

In terms of current dollars, total federal-state appropriations for agricultural research expanded very sharply from 1915 to 1984. This is shown in summary form in Table 2, column 1.[13] On the surface, there would seem to have been an enormous expansion in public funding for agricultural research.

But if the data are normalized on the basis of population, growth, and inflation, the situation becomes somewhat more muted. Accounting for population growth (Table 2, column 2) reduces the figures by more than half since the mid-1960s. Accounting for inflation, by using the consumer price index, makes an even more substantial reduction (Table 2, column 3): the constant dollar figure for the 1980-84 period was only slightly over 10% of the current dollar figure.

Even so, the per capita appropriations rose significantly in constant terms, from 7.5 cents (during the period 1915-19) to 68.9 cents (in 1975-79). Then, for the first time, they dropped in 1980-84. If the period 1915-34 is compared with the 1965-84, the appropriations increased 6.4 times.

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[12] Calculated from data used in the preparation of figure 7 in Dalrymple (1981a: 43).

[13] Actual expenditures, representing funds from other sources (such as earned income), would have been higher. Over the period, 66.6% of the funds came from federal sources and 33.4% came from state sources. The federal proportion was 70.5% during the first half of the period and 62.7% during the second half.

Table 2. Total Federal and State Appropriations for Agricultural Research, Total and Per Capita, Current and Constant Dollars, United States, 1915 to 1984

Five-Year Period	Average Total Appropriation (1)	Average per Capita Appropriation (2)	(3)
	Current US$ (millions)	Current US$ (cents)	Constant US$ (cents)
1915-19	9.92	9.66	7.53
1920-24	14.35	13.32	7.56
1925-29	20.89	17.53	10.14
1930-34	27.23	21.84	15.28
1935-39	30.23	23.40	16.78
1940-44	38.97	29.25	18.50
1945-49	62.00	43.27	19.95
1950-54	101.26	64.90	25.03
1955-59	165.69	96.69	34.48
1960-64	260.76	140.18	45.41
1965-69	413.68	209.31	62.22
1970-74	573.55	274.14	64.03
1975-79	938.43	425.89	68.92
1980-84	1,441.31	621.35	65.96

Sources: *Column 1:* Calculated from federal and state data provided in Latimer (1964), Dalrymple (1981b), USDA-CRS (1963-1967), and Myers (1986).
Column 2: Column 1 divided by total resident population, Bureau of the Census (1985 and annual issues).
Column 3: Column 2 divided by the consumer price index (1914=100). Data for 1915 to 1960 obtained from Bureau of the Census (1985 and annual issues) and recalculated on 1914 base.

Appropriations Relative to Income

While appropriations were expanding, there was also a growth in individual wealth. How does the increase in wealth compare with the increase in funding for agricultural research? To determine this, per capita appropriations for agricultural research were calculated as a proportion of per capita personal income (both in current dollars). Unfortunately, the personal income series does not start until 1929, so the period of coverage is somewhat shortened.

The figures, reported in Table 3, show relatively little variation over the 55-year period. There was a drop during World War II (1940-44), and the proportion peaked during the 1965-69 period. In recent years, it has dropped somewhat. The proportion in the 1980-84 period was only 17.9% higher than 50 years earlier in the 1930-34 period. The marginal change in appropriations in these terms has been slight.

Table 3. Appropriations for Agricultural Research as a Proportion of Personal Income, per Capita, United States, 1930 to 1984

Five-Year Period	Average Proportion
	percent
1930-34	0.0475
1935-39	0.0437
1940-44	0.0345
1945-49	0.0404
1950-54	0.0384
1955-59	0.0474
1960-64	0.0587
1965-69	0.0654
1970-75	0.0595
1975-79	0.0579
1980-84	0.0560
Average	0.0501

Source: Calculated by dividing per capita appropriations for agricultural research (current), summarized in Table 2, by per capita personal income (current) as reported in Bureau of the Census (1985 and annual issues).

Another dimension is that different income groups in society carry different tax loads: the wealthier pay more in absolute terms than the poor. Recently, White (1986) calculated the total taxes paid for agricultural research per family in the United States in 1980. The result is shown in Table 4.

The benefits of research from the consumers' point of view did not increase nearly as sharply as taxes.[14] The poor, because they spend a larger proportion of their income on food, gain relatively more than higher-income groups. And some producers or landowners may gain more than others. Thus, agricultural research does have a redistributive element to it.

Table 4. Total Taxes Paid for Agricultural Research per Family, United States, 1980

Income Class	Total Tax
Under $10,000	$2.41
$10,000-14,999	6.36
$15,000-19,999	9.70
$20,000-24,999	11.98
$25,000-34,999	16.63
Over $35,000	41.46

[14] The average benefits per family were calculated as $26.75, $30.61, $34.19, $39.26, $44.22, and $53.47, respectively.

Appropriations Relative to Tax Revenue

The final step is to examine the relationship between government appropriations for agricultural research and government tax receipts. This is also done by computing the former as a proportion of the latter. The results are summarized in Table 5 and in Figure 6.[15]

Table 5. Appropriations for Agricultural Research as a Proportion of Government Tax Receipts, United States, 1922 to 1984

Years/Period	Average Proportion	Years/Period	Average Proportion
	percent	1955-59	0.175
1922	0.197	1960-64	0.209
1927	0.210	1965-69	0.233
1932,34	0.313	1970-74	0.216
1936,38	0.254	1975-79	0.224
1940,42,44	0.191	1980-84	0.219
1946,48	0.125	Average, periods	0.215
1950,52-54	0.143	Average, individual years	0.207

Source: Calculated by dividing per capita appropriations for agricultural research (current) summarized in Table 2 by total federal, state, and local tax receipts as reported in Bureau of the Census (1985 and annual issues).

The average proportion allocated for agricultural research, two-tenths of one percent (0.21%), showed virtually no trend over the full period.[16] The annual variation was fairly wide prior to 1960 (high during the depression, low during World War II and in the immediate post-war years) but was much reduced after that. The peak figure in recent years was obtained in 1965.

Clearly, again, changes in appropriations for agricultural research as a proportion of tax receipts have been quite modest. It is unlikely that future years will see much change in this pattern; if anything, the chances of a relative decline in research appropriations presently seem greater than for an increase.

[15] Unfortunately, consistent data on total federal and state tax receipts are not readily available for every year prior to 1952, so the time series is incomplete. The reference here is general tax revenue: it excludes other forms of general revenue ("charges and miscellaneous"), income from utilities and liquor stores, and insurance trust revenues. In 1982, tax revenues represented 77.6% of total general revenues.

[16] When the federal and state data were separated for the period from 1968 to 1984, it was found that only a slightly higher proportion of tax funds were appropriated for research (0.233) at the federal level than was true at the state level (0.200). This is remarkably close.

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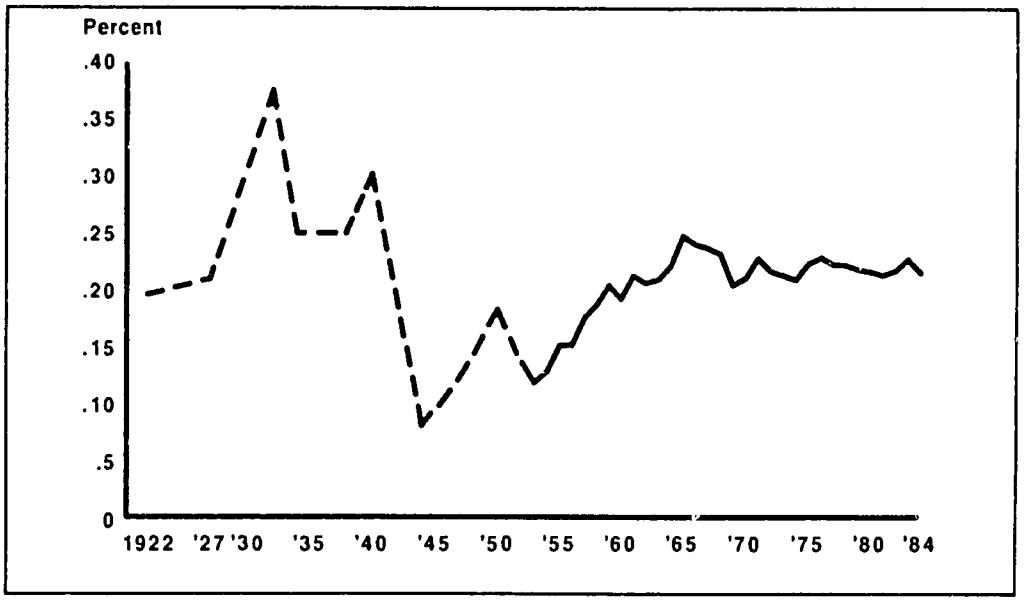

Figure 6. Proportion of government tax receipts spent on agricultural research in the United States, 1922-1984

Discussion

The concept of an excess burden of taxation has a long and noble lineage but has occupied a back room for most of its life. It, like the theory of consumers' surplus from which it is derived, is an intriguing concept but one that is difficult to measure or apply.

Public agricultural research would, however, seem to be an appropriate potential candidate for application of the concept. Much (slightly under half) of the agricultural research conducted in the United States is financed with tax funds.[17] Appropriations appear to have increased significantly over time. Moreover, many studies have been made of the rate of return to investment on this research. Should these returns be discounted to some extent, as Fox

[17] The public proportion has generally been thought to average about 50%. However, when calculated using the appropriation data cited in this report (which, as noted in footnote 13, are less than expenditures), the proportions are slightly lower — about 43.9% in 1965 (based on private-sector data reported in Wilke and Sprague [1967]) and 43.1% in 1984 (Agricultural Research Institute 1985). Based on expenditures, the 1965 proportion was 46.1%. It is not certain whether the private-sector data include producer checkoffs or levies on individual commodities for research; these are, in any case, of minor overall importance in the United States but are understood to be considerably more significant in Australia and Israel. For a further discussion of private sector research, see Peterson (1976) and Ruttan (1982).

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(1985) suggests, to take into account the excess burden associated with the collection of taxes?

A closer look at the concept of excess burden suggests a number of theoretical and practical questions that need to be considered before it is used. Some economists, as noted, have reservations about the realism of consumers' surplus.[18] And in the case of excess burden, a number of assumptions that limit the applicability of the concept do have to be made. Some of these constraints may be eased by shifting from a partial to a general equilibrium type of analysis, but other complexities are introduced. Most models have not allowed for the possibility that tax funds may be used for production-enhancing activities such as research.

The latter is an important consideration in the case of public agricultural research. The purpose of most (but not all) of this research is to shift the supply curve to the right and to reduce the cost per unit of production. Essentially all of this production is carried out in the private sector. Also, public-sector research usually complements research done by the private sector (Wilke and Sprague 1967). Thus, agricultural research clearly belongs in Harberger's (1964b) classification of technological change and Hansson's (1985) infrastructure category. And government-sponsored research is clearly a public good.[19]

In applying the concept of excess burden to agricultural research, however, it is important to differentiate between gross and net measures. The former, as we have suggested earlier, refers only to the effect of the tax irrespective of use. The latter takes the use of the funds into account. In his analysis of agricultural research, Fox (1985) drew a deadweight loss estimate from approximately the midpoint of the range cited by Ballard, Shoven, and Whalley (1985) (30 cents) and used it to discount returns to research.[20] This range of deadweight loss, as we have noted, (1) cannot be used for infrastructure or productivity-enhancing, nor (2) does it allow complementarity between public and private goods. Thus, it appears to have been a gross estimate and perhaps suitable for discounting rate of returns. But was it the most appropriate gross estimate? The figures vary widely, depending on how they are calculated, and it is not at all certain which would be most suitable for this purpose.

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[18] Clearly, this group would not include the many economists who have made use of producers' and consumers' surplus to evaluate returns to research.

[19] Mills (1986: 40-41) notes that this is more nearly the case for basic than for applied research. He indicates that about 65% of basic research and 45% of applied research is sponsored by the national government.

[20] In a subsequent study, Fox and Haque (1987) calculated the effect of increasing the MEB from 35 to 50 cents on the optimal level of research expenditures for crops and livestock: they were reduced by an average of about 10 %.

There is also a question of whether a marginal or average figure should be used.[21] Fox (1985) suggests that a marginal figure is justified because the share of public expenditure spent on research is small. This seems quite likely but was not documented. Review of the data on public appropriations for agricultural research in the United States over the past 70 years suggests substantial increases in appropriations, but when these are normalized on the basis of population growth and inflation, the figures are considerably reduced. They are lowered further when changes in personal income are taken into account. And when appropriations are considered as a portion of total tax revenue, very little change is apparent. Moreover, appropriations for agricultural research represent only a small proportion of income or tax revenue. Thus, both the marginal changes and average levels appear small. As is probably true in other sectors, the wealthier pay more for agricultural research and receive relatively less than the poor.

While all of this suggests that agricultural research is a relatively minor user of public funds in the United States (and a highly productive one at that), it does not mean that it is excused from the need for a certain amount of discounting when the time comes to calculate cost-benefit ratios or rates of return. The big question is what estimate of excess burden is most suitable for this purpose. Another question, which in part depends on the figure chosen, is the degree to which it will influence the outcome of the return calculations.

Although excess burden has been reviewed here in the context of agricultural research in the United States, the issues are equally relevant for public research in other nations and for other forms of government expenditure. Obviously, it would not be appropriate to discount only the returns from research in making comparisons with returns from other forms of government investment: all, or none, would have to be discounted. The issue can quickly become a larger one.

Thus, for some students of agricultural research, the concept of excess burden may not be entirely welcome. It provides theoretical complexities. It is difficult to explain. It is not easily measured. And its degree of influence on rates of return is uncertain. In short, it may appear to be more trouble than it is worth. But it cannot be readily dismissed by those who use the theory of consumer's surplus to measure returns to research. It is the other side of the coin that needs to be examined more closely.

[21] A more formal definition of each is provided in Ballard et al. (1985: 9, 237).

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PROBLEMS OF OMITTING PRIVATE INVESTMENTS IN RESEARCH WHEN MEASURING THE IMPACT OF PUBLIC RESEARCH

Carl E. Pray and Catherine F. Neumeyer

Abstract

In many countries, private companies do much of the agricultural research and development (R&D). In most studies of the impact of public agricultural research, the impact of private research has not been explicitly modelled. Three principal methods have been used to measure the impact of public research: (1) the index-number or consumer-producer surplus approach, (2) the productivity approach, and (3) the duality-based approach. Economists using the index-number approach have included estimates of the cost of private R&D in their calculations when estimating rates of return to public-sector research so that they do not bias their estimates of rates of return upward. Without data on private research, they have simply doubled the amount spent on public research to ensure that they were including all research. There are few published studies that include private research as an explanatory variable when using the productivity or duality approach. If private R&D is not included as an explanatory variable, estimates of the impact of public research may be biased. This paper draws on recent theoretical and empirical research on the impact of private-sector research in the United States and India to discuss the implications of leaving out private-sector research. It also addresses the direction of the biases and presents a preliminary assessment of their importance.

Introduction

The primary purpose of evaluating the impact of public research is to provide policymakers with insights to aid in decisions about future investments in research. Policymakers and research administrators must decide how much money to spend on research and how it should be allocated among different commodities, agricultural inputs, disciplines, regions, and basic versus applied research. If the interaction of public and private research is not explicitly modelled in studies evaluating the impact of public research, this may lead to suboptimal investments in research by the public sector. If the ex post calculations of rates of return are biased (because private investment has been omitted) they may lead to too little or too much investment in public research in the future. Even in the case where unbiased ex post calculations are used to justify investments, if a commodity, region, or time period has different institutions than those of the particular area under study, there may be different levels of private research and development (R&D), which results in over- or underinvestment in public R&D. Finally, if ex ante research studies leave out private research, they also may be biased and could lead to suboptimal investments in research.

Background

The importance of private-sector investment in R&D varies widely across regions and over time. Even within countries, there is wide variation among commodities. In the United States, the investment in private-sector research is concentrated in input industries and the food industry. Table 1 shows the breakdown of private and public R&D. In the first four categories, R&D is almost entirely conducted by input-supply firms, with a small amount being done by farmers. The last category is research by the food-processing industry.[1] The relative strength of public and private R&D varies substantially over time. Public-sector R&D is strongest vis-a-vis private R&D in livestock research, followed by crop breeding and management. Private research is strongest in the areas of agricultural chemicals (primarily pesticide research), postharvest handling, and mechanization.

In less developed countries, public research is concentrated on agricultural production, with very little postharvest research or research on input industries other than the seed industry. Private research, at least in Asia, is different from the pattern in the US (Table 2). Because of the importance of plantations, which do a lot of research in some countries, private research is very strong in the agricultural-production sector. In Malaysia and the Philippines, plantations make up most of the R&D included in the "Planta-

[1] This category does not include R&D in textiles and tobacco in 1984.

Table 1. Public and Private Expenditures in R&D in the US, 1961 and 1984

	1961		1984	
	Public	Private	Public	Private
	millions of 1984 US$			
Input Industries				
Crop Breeding & Management	156	68	228	474
Plant Protection & Nutrition	200	139	262	731
Livestock	149	113	359	197
Mechanization	17	53	13	85
Processing Industries	188	567	100	345
Total[a]	809	1,081	1,770	1,700-2,600

a. The total is not the sum of the columns because it includes other categories and expenditures that could not be classified.

Sources: 1961 is calculated from unpublished unscientific person-year data in Evenson and Huffman (forthcoming, Table 3.1), based on unpublished USDA data.
1984 public sector is calculated by using Huffman and Evenson (1988: Table 3.5, "major research foci") and USDA (1985). In addition to the postharvest foci of Evenson and Huffman, we added the food and textile commodity categories from USDA to get our postharvest category.
1984 private research aggregates the following categories from the Agricultural Research Institute (Appendix Table A.9):
Crop Breeding & Management = breeding + 0.62 × biotechnology
Plant Protection & Nutrition = pesticides + plant nutrients
Mechanization = farm machinery and equipment
Postharvest = human food + natural fiber processing + packaging.

tion and Processing" category in Table 2 (about 40% of all private research). The other 60% is carried out by input firms.

Model of Interaction between Public and Private Research

Figure 1 illustrates the main interactions between public- and private-sector agencies involved in developing new agricultural technology and in the transfer of technology to farmers. Technology is developed by public R&D, private R&D, or some combination of the two.[2] It is the interaction of public and private R&D that we will model in more detail here. Technology that is embodied in new inputs, such as an improved seed variety or machine, must be transferred to an input-supply firm or government agency. Then the new

[2] In an open economy, new technology can also be imported.

Table 2. Private-Sector R&D Expenditures in Selected Asian Countries, 1985 (in thousands of US$)

	India	Philippines	Thailand	Indonesia	Malaysia	Pakistan	Bangladesh	Total
Seeds	833 (8)[a]	1,583 (4)	665 (5)	0	0	182 (3)	<1,000 (1)	3,264
Pesticides	3,500 (20)	1,170 (8)	887 (5)	800 (1)	500 (3)	387 (5)	40 (2)	7,284
Machinery	6,775 (3)	0	0	0	?	0	0	6,775
Livestock	2,275 (3)	500 (6)	1,725 (2)	600 (3)	?	0	0	5,100
Processing and Plantations	3,324 (25)	1,137 (7)	1,034 (3)	600 (3)	10,000 (9)	234 (2)	50 (1)	16,379
Total Private R&D	16,707	4,390	4,311	2,000	10,500	804	90	38,802
Government-Funded Agricultural R&D[b]	248,000	7,000	78,595	6,700	4,400	56,170	8,000	
Private R&D as Percent of Government R&D	7.0	63.0	5.0	3.0	24.0	1.0	1.0	
Agricultural Value Added (billions of US$)	59.7	8.7	5.6	21.1	6.6	6.7		
Private R&D as Percent of Agricultural GDP	0.03	0.06	0.05	0.01	0.17	0.01	0.00	

a. Number of firms are shown in parentheses below the expenditure.
b. These numbers are not consistent in their inclusion or exclusion of capital expenditures. The Philippines does not include capital expenditures, but Pakistan does. With some of the others, it is unclear whether capital expenditures are included or not.
Source: Indian Department of Science and Technology (1984), data are for 1983; Sardido (1984), data for Philippines, 1984; Isarangkura (1986), data for Thailand, 1984; Oram (1987), data for Indonesia, 1984, and Malaysia, 1980; Pakistan Agricultural Research Council, data for 1984; Kaul (1987), data for Bangladesh, 1985.

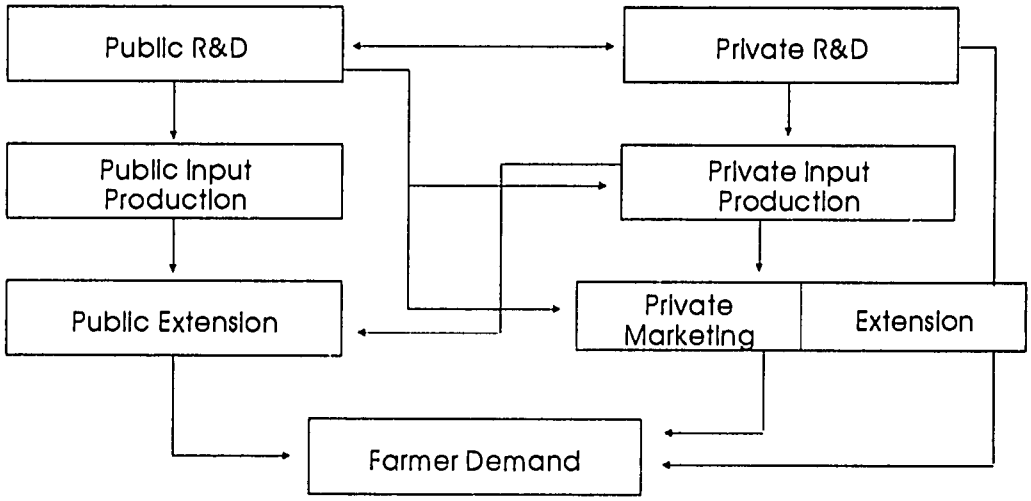


Figure 1. Research and technology transfer

inputs must be transferred to farmers through a public extension system or through private marketing channels. As the diagram indicates, the output of public research goes to both public and private producers and distributors. The output of research by input-supply firms is usually embodied in inputs; however, both public extension and private marketing play a role in spreading new technology.

Technology developed by private processing firms or by plantations is frequently not embodied in new inputs and goes directly from research to farmers, although in some cases it goes through a private extension service. If the means of producing new inputs and transferring technology do not exist, the best R&D in the world will not affect agricultural production. In this paper, we assume that technology-transfer institutions exist, but policymakers — particularly in less developed countries — must find out whether or not such institutions exist in order to assess possible returns from various public research projects.

The model developed here will be limited to the influence of public research on private-sector research. Although this influence also occurs in other direction, the impact of private research on public investments will not be discussed here. To model the impact of public research on decisions regarding investment in private research, it is useful to examine the incentives for private research investment. The usual model assumes that the firm will maximize its expected return to research investment. The objective function of the firm can be represented as

$$E(\Pi) = \int P_y Y - \Sigma X_i P_{xi} - r$$

where

$E(\Pi)$	=	expected profit
Y	=	output
P_y	=	price of output
X_i	=	input i
P_{xi}	=	price of input i
r	=	research investment

The firm's expected returns depend on the following: (1) the cost of R&D (i.e., the investment necessary to bring about new innovations), and (2) net revenues from new innovations. R&D results in innovations in the form of new or improved products and new process technology that has the potential to increase the firm's revenues or reduce production costs.

The factors that affect a firm's expected returns to research investments are listed below:

1. *Technological opportunity* (which influences the cost of research) affects the expected productivity of R&D investment. Technological opportunity is in turn affected by the stock of scientific knowledge (which is a function of past research in basic science). Thus, it is directly related to public-sector support for basic scientific research. An example of improved technological opportunity includes the recent discoveries in molecular biology that improve the productivity of research in seed companies by providing more efficient methods of screening genetic material for economically important characteristics.

2. *Appropriability* (which is the degree to which a firm is able to appropriate the benefits of an innovation) is dependent upon the technology of the innovation, the institutional environment in which the firm operates, as well as the market structure. The technology of the innovation may influence whether or not the innovation lends itself to protection under intellectual property rights. Some innovations are technically easier to protect (i.e., hybrids versus varieties).

   The institutional environment also has an effect on the ability of a firm to appropriate the returns to an innovation. Intellectual property rights in the form of patents and trade secrets are tools by which firms protect innovations. The set of property rights available to firms differs in different countries and by different technologies (i.e., many countries offer patents on mechanical inventions but not on living organisms).

Market structure also affects the degree of appropriability through its affect on a firm's ability to capture economic rents associated with a new innovation. The relationship between market structure and private-sector investment has been the subject of a large body of literature and empirical testing in economics.[3] One general hypothesis has been that the potential to capture economic rents from innovations provides an incentive for research investments by firms.

3. *Market demand* and factors affecting market demand also have an impact on a firm's incentives to invest in research. The size of the market (as well as the number and market share of competing firms) determine the potential revenues from new innovations. For example, agricultural crops grown over small areas may attract less research from the private sector than crops grown over wide areas. The public sector influences market demand through various policies that affect the demand for agricultural inputs, which in turn affects incentives for private research.

Most previous studies on the impact of public agricultural research have assumed either that private research does not exist (equation 1) or that it is independent of public research (equation 2).

$$Prod_t = f(PubR\&D_{t-n}, Ed_t, Ex, \ldots) \quad (1)$$

$$Prod_t = f(PubR\&D_{t-n}, PrivR\&D_{t-j}, Ed_t, Ex_{t-1}, \ldots) \quad (2)$$

where

$Prod$ = agricultural productivity
$PubR\&D$ = public R&D
$PrivR\&D$ = private R&D
Ed = rural education
Ex = extension
t = time period
$n > j$
the correlation of Pub and $Priv = 0$

There are at least three other interactions between public and private R&D. First, public research may stimulate private research (equation 3). This is the implication of the description of the development of hybrid corn in the classic article by Griliches (1957). Experiment stations in each state conducted the initial trials of hybrid corn cultivars. Then seed companies started selling public cultivars and developing their own hybrids for the

[3] See Kamien and Schwartz (1982) and Stoneman (1983) for reviews of this literature.

region based on inbred public lines. Private hybrid corn breeding in Thailand and hybrid sorghum and millet in India (Pray and Neumeyer 1988) are also examples of public research that stimulated private research. There was no private Thai corn research until the Kasetsart-Rockefeller-CIMMYT program identified genes resistant to downy mildew. The private pearl millet breeding programs in India are based on sterile male lines from the government and ICRISAT. In these cases, public research has stimulated the R&D of input producers. In the input market, it shifts out the demand curve for seed, and new seed makes farmers more efficient, which shifts down the supply of agricultural goods. The actual model is a system of equations which includes equations 2 and 3, where $\beta_{t-n} > 0$.

$$PrivR\&D_t = \alpha + \Sigma\, \beta_{t-n} \cdot PubR\&D_{t-n} + \delta\, (other\ factors) \tag{3}$$

Second, public R&D could *decrease* the amount of private research ($\beta_{t-n} < 0$ in equation 3). If public R&D is a substitute for private-sector R&D, firms may reduce their research. For example, a government program to develop new methods of integrated pest management for plantation crops may reduce the need for pesticide companies and plantations to do research in this area. Public research could also have an impact on the demand for private technology embodied in inputs. Public hybrid breeding programs could be sufficiently efficient or subsidized that they reduce the demand for private hybrids and thus the amount of private research. Public research could reduce the demand for certain innovations through reports on their negative environmental impacts, or it could reduce the appropriability of a new technology by publicizing the way the new technology was developed or publicizing the benefits of alternative products.

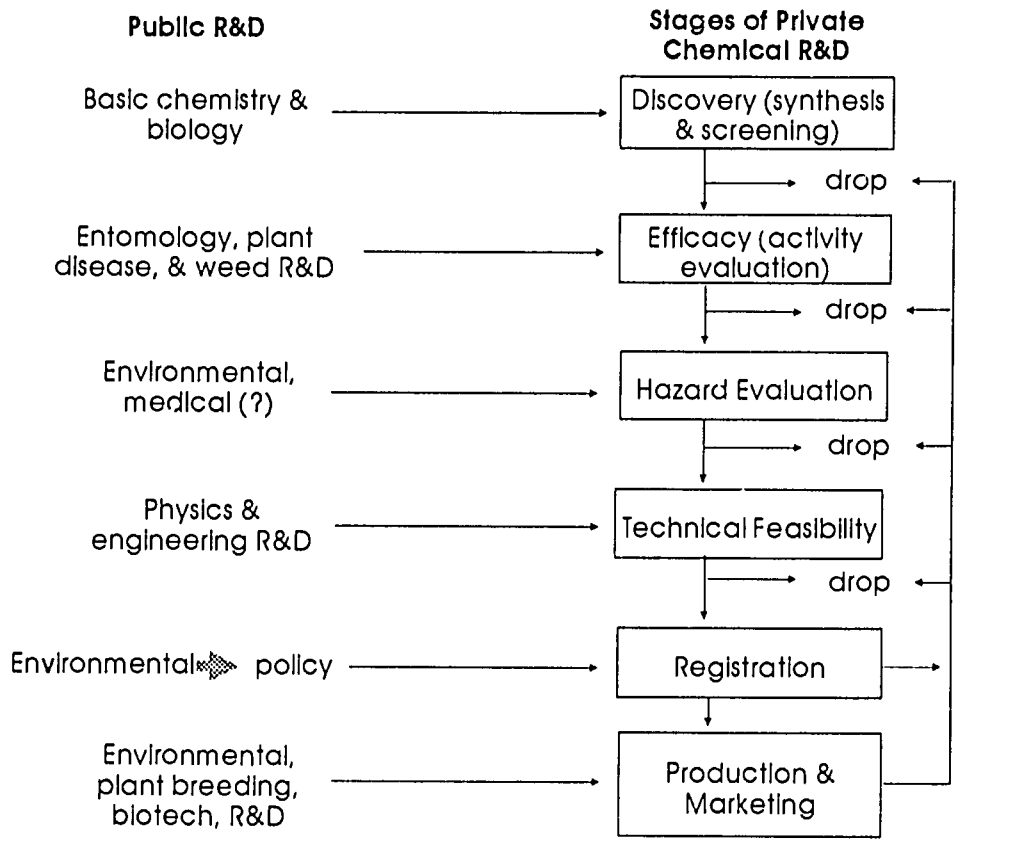
A third possibility is that the interaction between the public and private sector could be so close that they would be virtually indistinguishable. This could either be because of a formal relationship, such as a joint public-private research project, or because of an informal arrangement between public and private scientists. Then the relationship might be as specified in equation 4. In econometric analyses, expenditure on one could act as a proxy for both in regression analysis, but one would need the expenditure on both to calculate the rate of return correctly, using either the production-function or index-number approach.

$$Prod_t = f\,(ProdR\&D_{t-n} + PrivR\&D_{t-j}, Ed_t, Ex_{t-1}, \ldots) \tag{4}$$

A final possibility is that public-sector research could influence the direction of private research while not influencing the amount of money invested. Many government research programs conduct trials of different inputs. If these results are widely publicized and the government program has credi-

bility with farmers, companies in a competitive industry will then be forced to conduct research to enable their technology to excel in these trials.

One problem in the real world is that different types of public research push private R&D in different directions at the same time. Thus, the estimated relationship between public and private research depends on the weights of these interactions in the aggregate of research being measured. Figure 2



Source: Hatch (1982).

Figure 2. Stages of research and development for a new pesticide

shows the different stages of R&D for a new pesticide on the right. After each stage, companies decide to drop some of the new chemicals that were synthesized in the discovery stage and to move other chemicals to the next stage. Those decisions are based on technical considerations and on the production and marketing possibilities. Public research that can affect private research is listed on the left. Public research affects both the technical and marketing components of the decision to drop a chemical.

Advances in public R&D at the top of the figure can help companies conduct research more efficiently at each stage and can also help them make fewer mistakes about which compounds to drop and which to continue. Increased R&D efficiency should lead to more private research.

The public research listed toward the bottom of the figure could reduce research productivity and would thus have a negative impact on private research. For example, environmental research that leads to more stringent regulatory policies would make it more expensive to bring a new product to market and would reduce the incentive to do research in that product area. At the very bottom, there are a number of types of public R&D that might affect the size of the market for a pesticide. This feeds back to the decisions made during the research process on whether or not to drop a potential product. Environmental research could decrease the demand for chemical pesticides. Plant breeding and biotechnology could develop cultivars that do not require pesticides.

Measuring the Impact of Public Research Investments

There are primarily three methods that have been used to measure the impact of public research: (1) the index-number or consumer-producer surplus approach, (2) the production-function or productivity approach, and (3) the duality-based approach. Norton and Davis (1981) provide a useful review of the literature on the use of techniques 1 and 2 up to 1980.

The index-number approach has been used more than any other method. The vast majority of studies assume that public-sector R&D directly affects agricultural productivity and shifts the agricultural supply curve downward. This downward shift is signified in the literature with k or K. The shifter — the difference between the actual and the *counterfactual* supply curve — is generated in a number of ways, which are reviewed in Norton and Davis (1981). In ex post analysis, the correct specification of the counterfactual supply curve is the main difficulty. The appropriate supply curve without technology depends in part on what the private sector would have been doing in the absence of public R&D. In ex ante analysis, the supply, both with and without the new technology, has to be projected.

When estimating rates of return to public-sector research with the index-number approach, most US economists include estimates of the cost of private R&D. They do this to ensure that their estimates of rates of return are not biased upwards. Since data on private research are rare, these economists simply double the amount of public research to ensure that they are including all research.

Peterson (1966) is one of the few economists who have explicitly controlled for the impact of private research in their estimates of the shift in the supply curve attributable to public research. He looks at the determinants of eggs per laying hen in the US. His independent variables include public research on poultry, the quality of chicks, and the quality of feed, which he says are related to a combination of public and private research. Then the supply shift attributable to public research is calculated from the estimated coefficient of the public-sector variable.

Most index-number studies divide the economic benefits between producers and consumers. The key parameters in determining the proportion that goes to different groups are the agricultural supply-and-demand elasticities. A few analyses have also looked at the impact on certain inputs — primarily labor (Schmitz and Seckler 1970). Somewhat surprisingly, we know of no study that calculates the benefits to input-supply companies in addition to the benefits that go to farmers.

In recent years some index-number studies have moved away from focusing on the shift of the agricultural supply curve. Unnevehr (1986) has estimated the impact of quality change by estimating the shift of the agricultural demand curve. The University of Florida, Gainesville, has conducted some studies to measure the impact of postharvest research (Langham and Purcell 1987). Freebairn, Davis, and Edwards (1982) have presented a framework for estimating the impact of productivity change in agriculture, the input industry, or marketing on the other industries.

The production-function approach was the other mainstay of research evaluation until the last few years when the duality approach became popular. The basic model used by this approach is a Cobb-Douglas production function with conventional inputs (like fertilizer and machinery) and lagged nonconventional inputs (like public R&D) as the arguments. When using time-series data, economists have used a productivity index as the dependent variable, with weather, educational level of farm workers, lagged public R&D expenditure, and perhaps public extension as independent variables. This specification helps reduce collinearity problems in estimating the impact of R&D.

The literature on duality provides a framework for examining the impact of simultaneous shifts in agricultural supply and input demand due to public-sector research. The duality approach is derived from the dual relationship between the profit function (or cost function) and the underlying production technology. Using this approach, product supply and input demand functions can be derived from a multiproduct profit function.

The demand-and-supply equations can be specified as functions of product prices, variable input prices, levels of fixed inputs, plus levels of nonconventional inputs such as the stock of public-sector research investment, extension expenditure, and educational achievement. These output supply and input demand equations are then estimated.

This approach offers a number of advantages over the production-function approach because the supply-and-demand functions can be estimated using price data rather than physical quantities for the variable inputs. A multiproduct profit function (in which there is joint production) can be employed. In addition, the impact of research, extension, and education can be obtained on input demand as well as output.

Only in the past few years have public-sector research investments been explicitly specified as a variable in the duality approach (Huffman and Evenson 1988); previous studies used time as a proxy for technological change. Private-sector investments in research have not yet been incorporated into the duality approach, primarily because of the lack of data in this area.

India Case Study: Possible Biases Using the Index-Number Approach

Government research administrators in India must decide how to allocate resources among a number of commodities and different types of research within each commodity. Research administrators can look at ex post studies of the returns to research on these crops (assuming that these returns will continue into the future) and can then allocate research support to those crops that give the highest returns. Another method is to do an ex ante cost-benefit analysis of alternative public-research strategies. Both of these methods result in erroneous projections if the role of the private sector is not explicitly considered.

Studies of past public research in India indicate that there have been very high returns to public-sector research. Table 3 shows estimates of expenditures on research by the public and private sectors and our estimates of the social benefits from these expenditures. Government research on hybrid pearl millet started with the introduction of sterile male lines from Georgia in the early 1960s. ICRISAT started research on this crop in 1972. Research by private companies started around 1970, but only a few companies were involved in research prior to the mid 1980s. Today at least 16 companies have pearl millet breeding programs.

The last column in Table 3 shows the benefits from both public and private pearl millet cultivars. As in any standard cost-benefit analysis, the benefits

Table 3. Pearl Millet Research Expenditures and the Stream of Benefits from Research by the Private and Public Sectors in India

	R&D Expenditures			Social Benefits	
Year	Public[a]	ICRISAT[b]	Private[c]	From Private R&D[d]	From Public R&D[e]
	thousands of 1986 Rupees				
1960	116				
1961	120				
1962	125				
1963	130				
1964	143				
1965	154				
1966	173				
1967	199				9,826
1968	198				9783
1969	202				9,988
1970	215		45		10,599
1971	225		50		11,133
1972	245	181	60		357,513
1973	285	245	81		415,989
1974	367	405	134		534,898
1975	381	437	145	9,214	555,749
1976	374	421	140	9,036	892,954
1977	402	1,108	327	9,717	960,250
1978	1,382	1,103	326	9,696	958,195
1979	1,540	1,369	405	10,802	1,067,486
1980	1,853	1981	586	12,996	1,284,271
1981	2,079	3,120	797	14,586	1,809,289
1982	2,130	5,203	,155	14,941	1,853,296
1983	2,478	7,175	,344	16,119	2,587,060
1984	2,692	9,502	1,722	17,496	3,231,469
1985	3,986	11,246	3,871	20,390	3,310,764
1986	4,200	12,990	4,192	151,774	3,488,625

a. Source: Ramachandran (1979).
b. Estimated from the annual data in CGIAR (1987). Using actual 1965 millet program R&D costs as a proxy, approximately 5% of total expenditures over the years is attributed to the millet breeding program.
c. Source: Survey of Indian Private Seed Industry, August 1987 and personal interviews.
d. Private Research Benefits:

$k = 0.25$ $y = 1000$ kg/ha $e = 1.7$
$n = 0.4$ $p =$ Rs. 1.4/kg economic surplus/ha = 390.

The Akino/Hayami methodology was used. Private hybrid acreage data are from survey.
e. Public Research Benefits:

$k = 0.40$ $y = 1000$ kg/ha $e = 1.7$
$n = 0.4$ $p =$ Rs. 1.4/kg economic surplus/ha = 644.5.

Acreages on HYVs are from Jansen (1988).

from public hybrids and varieties are included. Benefits from private hybrids are also included because they would not have been produced if there had been no government research program. All private hybrids are related to public, sterile male lines and other genetic material from the Indian government or ICRISAT. Pearl millet is not an important commercial food crop in most developed countries; therefore, there was little foreign technology that companies could readily borrow. In the absence of public research, a firm would have had to screen germplasm until it found male sterility and then identified lines which would cross well with the male steriles to produce productive hybrids.

This is a time-consuming and expensive process, and it is unlikely that a private firm would have undertaken this research in India. At present, only one or two companies are attempting to develop their own inbred lines. Thus, calculating benefits as the distance between the actual supply curve and a supply curve that assumes no hybrid varieties is appropriate. Private R&D would be accounted for in the new supply curve because its cost would be included in the price of seed. We have calculated that the average returns to public pearl millet research was in excess of 100%.

Rates of return could also be calculated for the other major crops; however, it would be misleading to use these rates of return to allocate resources among different commodities. There are very different amounts of private plant breeding in the five major grain crops — wheat, rice, maize, sorghum, and pearl millet. There is none in wheat and rice, a small amount in maize, and a large amount in sorghum and pearl millet. Expected future returns to public breeding in wheat and rice may be similar to past returns, so increased breeding could be expected to lead to high returns.

Private research in maize, sorghum, and pearl millet is a very recent phenomenon. We can not expect future returns to public research to be the same as ex post returns because public research to develop new hybrids may duplicate research currently being done by private firms and hence may have a low or even negative return.

Calculating the social returns to private research is useful if governments are considering policies that would subsidize or restrict research in the private sector. Some government scientists and research administrators in India and elsewhere say the following: "We are developing new varieties. Why do we need private breeding?" The contribution of private research in pearl millet is quite clear — private companies have spread hybrids that are resistant to the latest strains of downy mildew while government hybrids that incorporate these characteristics are just coming on the market. The returns to this research have been very high — 170% — indicating that the

decision to allow private research was a wise one and that the government should consider the possibilities of subsidizing private research.

Private firms do not conduct research for the public good. Rather, they do research to make money. If the returns that they can capture from research are not higher than possible returns from other investments, they will invest in other things. To substantiate this, we have also calculated the financial returns to private research. These are on the order of 20% for pearl millet.

To calculate ex ante returns to research accurately, one has to specify the future role of the private sector. This requires information on current trends in private R&D and on some of the factors that will influence future spending, such as market structure.

A number of scenarios need to be examined in an ex ante analysis of sorghum and pearl millet research. A recent survey of the R&D activities of Indian seed companies shows that the industry is characterized by the following relationships between public and private breeding:

1. Both the public sector and private firms are breeding commercial pearl millet hybrids (duplication of private research).

2. Public research has identified sources of pest resistance and increased yields, incorporating these characteristics into new hybrids. (This activity does not duplicate the research of the private sector. Only a few Indian companies are trying to produce their own lines and even they depend on public germplasm.)

3. In the future, following the trend in other areas of the world, increased basic R&D on pearl millet by the public sector would enable public and private breeders to incorporate characteristics like drought resistance or improved quality into commercial hybrids in 10 to 15 years. Grain quality is very important with the millets, and it is one of the easier characteristics to engineer genetically or at least one of the easiest for which improved screening methods can be developed. Public R&D in biotechnology could increase the opportunities for private companies to profit from plant breeding and lead to increased private R&D on pearl millet.

In this section we consider three policy alternatives and some of the likely impacts of these policies.

First, increased public R&D in breeding new hybrids: If one assumes no private-sector involvement, then more public research would increase the total effective R&D on pearl millet, and yields would increase. Based on our

observations, more public research may simply duplicate private-sector efforts; thus, this may not result in any increase in the number or quality of the hybrids being produced. Benefits would not increase but the cost of public R&D would.

A second alternative would be to reduce public research on maintenance of pest and disease resistance. This would quickly lead to a decline in benefits in pearl millet, where there seems to be an attack of downy mildew every five to eight years (even with current levels of private research). In the absence of public research, recovery might be faster because a few companies are trying to develop their own disease-resistant lines and others might join them if the public sector was not working in this area. If private companies did not respond, however, it could lead to a situation in which there were no hybrids resistant to the next generation of downy mildew and yield would decline drastically.

The third alternative would be to cut public breeding, increase basic research, and keep maintenance research constant. Breeding new hybrids would be left to the private sector. The public sector would work on understanding the genetics of pearl millet and improving its quality, stress resistance, and yield. If private breeding continued, the benefits from conventional breeding would not decline, and in 10 to 15 years, when biotechnology R&D started to produce practical results, benefits from public research would increase through the increased yields of private hybrids.

In all of these policy changes the benefits from research depend on whether or not there is an active public sector. The returns from the first policy alternative could actually be negative rather than positive, if private research already exists. In the second case, the results would depend on whether or not there were sufficient incentives to which the private sector could respond to determine how large the change in yields and, thus, benefits would be. The third policy could yield positive or negative returns, depending on the nature of the public-private interaction. The policy implications also depend on whether or not there is an active private sector. The government may want to shift its investment from plant breeding to maintenance R&D, and more long-term research on biotechnology could be given funds previously spent on public breeding.

United States Case Study: Biases Using the Production-Function Approach

There is far more research conducted by the private sector in the United States than in India, and its share of total agricultural research is far greater. In addition, there are far more data, and many more studies have been conducted on the rates of return to public research in the United States.

However, until the last year or so, there have been few attempts to explicitly model the interaction between public and private agricultural research. Now we are working on modelling the determinants of private research at Rutgers (Pray, Neumeyer and Upadhaya 1988), and Robert Evenson and his colleagues at Yale (Evenson 1988) are attempting to estimate the separate impacts of public and private R&D on agricultural productivity in the United States.

Our hypothesis about the relationship between public and private research in the United States is that public research creates technological opportunities for private R&D and thus stimulates more private R&D. As noted above, some public research also has a negative impact on private R&D, but it is our hypothesis that the negative impact is probably outweighed by the new technological opportunities created by public research. In preliminary tests of this hypothesis, we did find empirical support for it. If public and private research are positively related and the private research variable is left out, the regression estimates of the public-sector coefficient will be biased upward.[4]

Evenson (1988) assumes the independence of public and private research. Their early results suggest that private and public research both have a positive influence on research productivity. Furthermore, these results indicate that adding private research does not reduce the size of the coefficient on public research.

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[4] Biases arising from the omission of private-sector research:

Let PU = public R&D investment
PR = private R&D investment
X_1 = other inputs
Y = output

True Model: $Y = \beta_1 X_1 + \beta_2 PU + \beta_3 PR + e$ (1)

Estimated model: $Y = b_1 X_1 + b_2 PU + \mu$ (2)

$$b_2 = \frac{\Sigma PU\, Y}{\Sigma PU^2} = \frac{\Sigma PU\,(\beta_1 X_1 + \beta_2 PU + \beta_3 PR + e)}{\Sigma PU^2} = \frac{\Sigma PU\, X_1 \beta_1}{\Sigma PU^2} + \frac{\Sigma PU\, \beta_2 PU}{\Sigma PU^2} + \frac{\Sigma PU\, \beta_3 PR}{\Sigma PU^2} + \frac{\Sigma PU\, e}{\Sigma PU^2}$$

$$= \beta_2 + \beta_1 \frac{\Sigma PU\, X_1}{\Sigma PU^2} + \beta_3 \frac{\Sigma PU\, PR}{\Sigma PU^2} + \frac{\Sigma PU\, e}{\Sigma PU^2} = \beta_2 + \beta_1 Z + \beta_3 P + \frac{\Sigma PU\, e}{\Sigma PU^2}$$

$$E(b_2) = \beta_2 + \beta_1 Z + \beta_3 P$$

where the expected value of the last term = 0

Z = the coefficient resulting from regressing X_1 on PU
P = the coefficient resulting from regressing PR on PU

If we assume that the relationship between the other input, X_1, and public research is independent, three biases are possible on the public-research coefficient:

If $\beta_3 P > 0$, then the estimate of b_2 is biased upwards.
If $\beta_3 P = 0$, then the estimate of b_2 is unbiased.
If $\beta_3 P < 0$, then the estimate of b_2 is biased downwards.

If the impact of public research has been overestimated, then the argument may not hold that government expenditure on agricultural R&D is too small. Even if the impact of public research has been correctly estimated at the aggregate level, there is still a need to examine the interaction at the disaggregate level. Some types of public research will have a negative effect on private research and some will not have any impact at all. In order to allocate research resources efficiently, estimates of the different impacts on private research are important. It is also important to keep in mind that factors such as institutional arrangements will influence private-sector investments in research; thus, changes such as the recent decisions on the patenting of living organisms in the United States should affect levels of private-sector investments in research.

Summary and Conclusions

Private agricultural research is important in certain countries, commodities, and industries. In less developed countries, it is usually small in aggregate, but it has been growing rapidly in some commodities.

The interaction between public and private research has rarely been explicitly modelled. Private companies base their decisions on how much to invest in research by estimating the increase in profits that can be expected from that research. Expected profits are primarily due to three factors: (1) technological opportunity, (2) the firm's ability to appropriate benefits from research, and (3) the size of potential markets for the products of research. Public research primarily affects the technological opportunities and the potential market, but it can also affect appropriability.

Public R&D can have either a positive or negative influence on the amount of private research, or it may have no influence at all. If it has a positive or negative impact, then when calculating the benefits of public research, one must also add or subtract the benefits coming from private research.

The Indian case study shows some of the dangers of ignoring the private sector in measuring both ex post and ex ante rates of return. Because private research has developed only recently, ex post returns give little indication of ex ante returns. The ex ante evaluation of different distributions of public R&D on pearl millet shows that the existence of private plant breeding could change the optimal allocation of public research.

The US case study illustrates the possible biases that could arise from ignoring private R&D when using the production-function methodology. In this case, the returns to public research in the US may have been overestimated. It is particularly important to include the private sector when allocating research resources to alternative commodities and disciplines.

It is necessary to include private R&D when evaluating the impact of public research. If it is not included, the estimates of returns to public research are likely to be biased, and policy recommendations may be suboptimal.

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Regional Cases

ASSESSING THE IMPACT OF FARMING SYSTEMS RESEARCH AND DEVELOPMENT EFFORTS: AN ACTION-TRAINING METHODOLOGY

Phillips Foster, Marcus Ingle, and Barton Clarke

Abstract

This paper describes an action-training methodology used to conduct an impact assessment of the farming systems project conducted by the Caribbean Agricultural Research and Development Institute (CARDI) in eight countries of the Caribbean. The action-training methodology was used to introduce and field test impact assessment concepts in the Caribbean during a week-long workshop attended by 25 research staff from eight Caribbean countries. Key features of the methodology and issues arising from the use of this approach in the farming systems context are discussed. Sample workshop materials and a bibliography are included.

Some Perspectives on "Impact Assessment"

Virtually all research institutions monitor their research projects for financial and bookkeeping purposes. In addition, many attempt to evaluate the quality of their research. Unfortunately, few research institutions commit significant resources to the process of evaluating the social and economic impacts of their research.

There are several reasons for their reluctance to do so. Perhaps some of this unwillingness stems from the feeling that research resources are scarce; the benefits are obvious and we should therefore simply get on with the process. Perhaps some of the unwillingness stems from a fear that evaluation of research results would produce unfavorable benefit-cost ratios. And perhaps some of the unwillingness stems from the methodological difficulties encountered when establishing the benefits from some types of research.

It is unfortunate that agricultural institutions spend so few resources on attempting to measure the impact of their research on society because we ought to know the results of such spending. We ought to know if it pays and if so, how much it pays.

Assessing the impact of research and development attempts to quantify the costs and benefits from research and development activities. The methods used are not particularly arcane. Engineers and bankers regularly do benefit-cost analyses — there's no reason agriculture researchers shouldn't have the capability to do the same thing. The impact of applied research and development is relatively easy to identify and the payoffs are usually very high.

Some Perspectives on "Action Training"

The concept of action training involves a hands-on training program custom-tailored to a specific group of people who are established as actors in an ongoing system.

Action training has become a recognized strategy for improving managerial capacities and has emerged in various forms under a variety of names, such as "action training and research" (Gardner 1974), "action-training" (Solomon 1978; Solomon et al. 1977), "action learning" (Revans 1972; McNulty 1979; Harris 1981), the "performance approach" (Kettering 1985), and "capacity-building" (Honadle and Hanna 1982).

Although there are variations in action-training designs, action training is characterized by five factors: (1) it is performance-oriented, (2) it is situation-specific, (3) it is systematic, (4) it has a capacity-building orientation, and (5) it involves integration of training, research, and consulting.

In *Managing Training Strategies for Developing Countries*, Kerrigan and Luke (1987) describe action training as follows:

> The action training (AT) approach is based on an expanded conceptualization of "training," in that management training involves more than attending courses, seminars, and workshops, and requires more than the one-to-one interaction of on-the-job training. This approach links the training to a specific, tangible project, not an anticipated, future event. AT deeply involves the training participants in action, rather than allowing them to be passive recipients of someone else's wisdom and knowledge. AT imports less outside expertise and, instead, utilizes the direct experience of the managers themselves. The training occurs during the implementation of a particular project and is related to specific here-and-now problems. AT has its theoretical foundations in

> adult learning theories. AT involves looking at both the organization's structure and systems, as well as at the human relationships within the organization. AT intervention concentrates on getting agreement on goals and strategies, commitment to those goals, building teams, identifying the work to be done, clarifying the organization structure, specifying roles and responsibilities, and building skills.

This paper reports on the methodology used in a one-week action-training program to teach basic skills in impact assessment. The program was carried on with staff involved in farming systems research and development (FSR/D) activities with the Caribbean Agricultural Research and Development Institute (CARDI).

Workshop Objectives and Methodology

A four-day workshop taught by three members of a technical-assistance team was conducted for 25 participants, most of whom were researchers involved with the FSR/D project. The workshop was divided roughly into two periods: two days of classroom training about benefit-cost assessment and two days of field work to gather data and process these data in an impact-assessment framework.

The CARDI workshop had three objectives:

1. Participants would leave with at least some mastery of state-of-the-art concepts in impact assessment.

2. Participants would acquire enough confidence in the technology of impact assessment to put together the basic materials for a simple impact assessment and do a legitimate, if preliminary, run-through of the analysis.

3. Participants would become less fearful about "evaluation" of their research and development efforts.

Before the program, some (if not all) of the researchers feared that evaluation would mean negative criticism of their efforts. They were also concerned that their analysis might show that the benefits from CARDI were less than the costs incurred.

These fears generated some resistance to the workshop itself as well as to the method of analysis proposed. Even before presentation of the analysis, the researchers urged us to consider benefits that were questionable in concept and difficult to measure.

We were hopeful that by using the best techniques available for legitimate impact assessment, the results would show a favorable benefit-cost ratio and would assist both researchers and administrators in justifying their work.

Our first workshop objective involved state-of-the-art concepts in impact assessment. An action-training methodology may seem at first glance to be centered on methods of communication and human interaction, but in order for people to carry away from the workshop the appropriate set of skills, the methodology must be woven around the challenge of *content*. Therefore, we discuss the workshop methodology in the context of content (which was the methodology of impact assessment), just as we planned the methodology of the workshop presentation in the context of this content.

The action training program was carried on in a workshop held at a conference center in a rural setting.

Reading Assignments

Before the conference started, participants were given copies of four conceptual papers to read, along with recommendations on where to focus their reading (Griliches 1958; Evanson and Flores 1978; CGIAR 1985; Dalrymple 1986).

Programmed Exercises

On arrival at the workshop site, participants were given three short programmed exercises on discounting (present value, benefit-cost ratio, and internal rate of return) to complete before the formal opening ceremonies. Programmed exercises are excellent learning aids because of the following:

1. They keep the learner active in the learning process. (Students are repeatedly asked to process the material in their minds and write responses in the blanks provided.)

2. Correct responses are reinforced immediately. (Students can tell whether or not their responses are correct by proceeding a little further in the exercise.)

3. Incorrect responses can be corrected immediately with no embarrassment to the learner.

Four other programmed exercises tailored for this set of participants were used during the workshop as a means to deepen understanding of some of the more difficult concepts.

Lecture/Discussion

The first formal lecture/discussion was designed to reverse the traditional information flow almost immediately. In a benefit-assessment module, participants were put into discussion groups where they were encouraged to exchange ideas and brainstorm to develop a wide variety of benefits from their research or development activities. Then they reported back to the general group.

This activity served not only to introduce the participants to the variety and complexity of possible benefits from their activities, but brought them immediately into the conference as players — not just spectators.

Various sessions were led by the different members of the technical assistance team, which provided a change of pace. The welfare economics background of impact assessment was presented.

During the next session, three basic concepts useful to doing impact assessment were introduced: identifying the technology to be evaluated, making the *with* and *without* test, and the elements of financial versus social accounting. A programmed exercise then reinforced the ideas on social accounting and simultaneously provided a change of pace.

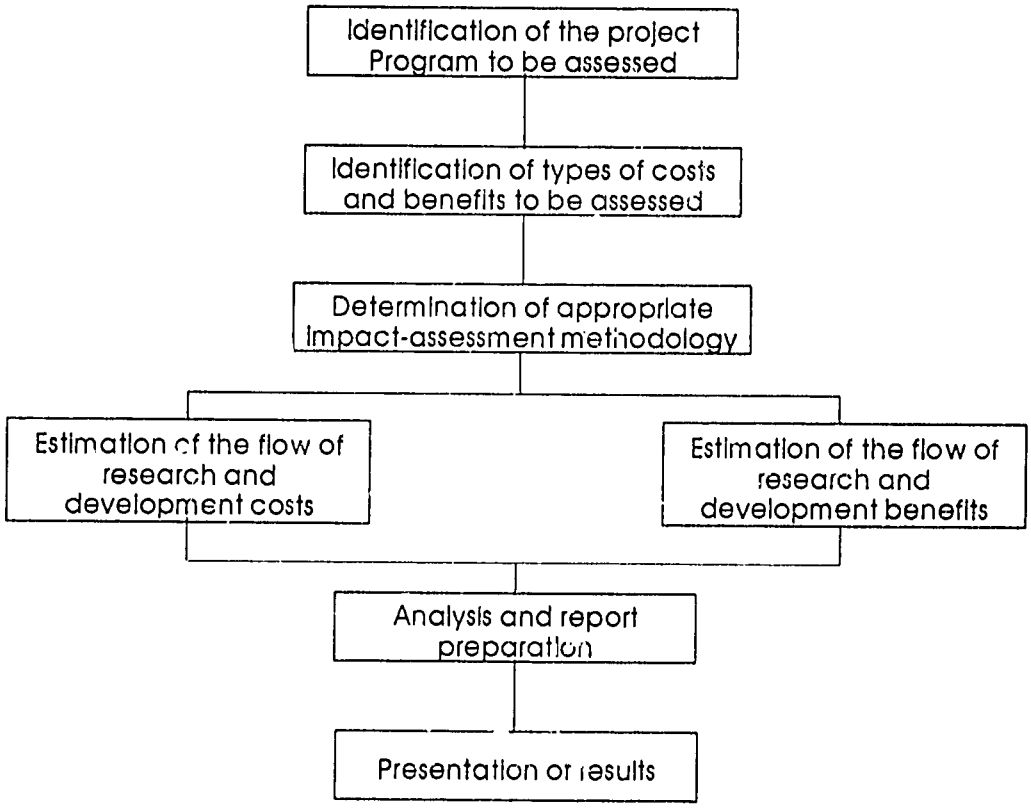
Coffee Breaks and Other Open Time

Workshop planners sometimes fill every minute of available time during the workshop with presentations and activities. However, both participants and leaders need frequent breaks for rejuvenation, socialization, and perhaps most important, informal feedback. We were careful to schedule frequent breaks during the day and no substantive sessions during the evenings.

Visuals

Flip charts and overhead transparencies are optimal visuals for the workshop setting, and they can be used in a lighted room. Properly used, they present material in a bold, colorful, easily readable format. Figures 1 and 2 illustrate the content of flip charts that we found useful for stimulating thinking early in the workshop.

Flip charts and overhead transparencies can be prepared in advance yet be modified on the spot. They can also be prepared from scratch on the spot when new materials are developed or reports of small groups are given.



Source: Adapted from Martinez and Saln (1983).

Figure 1. Stages of the agricultural research and development impact-assessment process

Flip charts are especially useful for presenting material that is to be posted for a prolonged period. Sometimes it is useful to refer back to a flip chart that was presented earlier.

With luck, skill and a few teaser strips, a flip chart can be used to outline key elements of information elicited from the participants and at the same time provide key words explaining at least some of the concepts. One flip chart, prepared in advance for the session on identifying costs, both financial and social, is a good example (Figure 3).

Data-Gathering Field Trip

The training during the first two days was designed to prepare the participants to identify and estimate the financial and social costs and benefits of a particular research or development innovation.

Research and Development Stages

Design of R&D Activities	Conduct of R&D Activities	Adoption and Use of R&D Activities

Types

Ex ante Impact Assessment ——— On-going Impact Assessment

Uses

1. Assist in selecting among alternative R&D activities using economic justification.
2. As policies change, be able to repackage investment in economic terms so activities can be continued.
3. Meet administrative requirements of donor planning systems.

1. Assist in determining long-term returns on investments in agricultural research development.
2. Assist in validating assumptions made during ex ante analysis for use in future projections.
3. Meet contractual requirements for evaluations.

Note: Agricultural research and development is defined as involving improved technology for policy formulation/implementation, technologies for structuring research organizations, and technologies for production and marketing.

Figure 2. Stages and uses of research and development impact assessment

Costs

Goods and services, e.g., purchased inputs

Labor and management (and associated costs)

Opportunity cost of land used

Taxes (a transfer payment in social accounting)

Interest (a transfer payment in social accounting)

Subsidies (a transfer payment in social accounting)

Depreciation is not a cost!

Figure 3. Sample flip chart

For the data-gathering field trip, the participants were divided into five groups and sent out to gather data on five different technological innovations that were in various stages of development.

One point of the exercise was to show that, no matter how small the operation, quality techniques of evaluation can be utilized at relatively low cost. A description of the five projects analyzed will show how very small some of the operations were. (Table 1 gives an overview of the five projects.)

Table 1. Initial Impact Assessment of CARDI FSR/D Technologies

Technologies generated through FSR/D project	State of technology	Benefit development	Costs of technology development	Preliminary benefit-cost ratio
1. Cut-&-carry fodder production	Refinement on several farms	Fodder production, time savings, & milk production	Medium	Positive: Medium
2. Tanya treatment	Transfer by CARDI & extension service	Successful on several farms	Medium	Positive: High
3. Dasheen treatment	Ready for transfer	Spoilage control	Low	Positive: High
4. Biogas production	Being transferred by CARDI, MDA, and SPAT*	Slurry for fertilizer; biogas for home use	Very low	Positive: Low
5. Vegetable production	Transfer by CARDI & extension	Compost for vegetable production	Low	Positive: Low

*Small Projects Assistance Team, funded by CDB/German Agency for Technology Exchange.

Cut-and-Carry Fodder

Sudan grass was grown on a steep slope just uphill from a pen where two cows were kept for milk. The grass was cut and carried to the cattle, and water, collected from a corrugated tin roof over the pen, was made continuously available to the animals. These activities replaced the traditional feeding and watering system, where the cows were staked out at various locations during the day and walked to a water hole once a day. The benefits of the new system included time savings for the farmer and increased milk production because of higher water and feed consumption.

Tanya Treatment

The aroid, tanya, was treated with metalaxyl (Ridomil) or benomyl (Benlate) fungicide before planting to reduce field damage from pythium during growth. A few years ago, many of the Caribbean islands were swept with the

fungus pythium and the tanya industry was all but destroyed. The technology, which is being successfully applied on one farm, promises to rejuvenate the industry.

Dasheen Treatment

The ariod, dasheen, was treated with metalaxyl (Ridomil) or benomyl (Benlate) fungicide before being shipped to England in order to retard spoilage from pythium. The new treatment extends shelf life by approximately one month. The technology applied here was rejuvenating a shipping industry that had all but died.

Biogas

Biogas is produced from manure from domestic livestock (chickens, pigs, cows, donkeys). Limited amounts of biogas are being produced for a few rural households.

Vegetable Production

Vegetable production was enhanced through applications of cow manure. Modest increases in production were noted.

The scale of these projects hardly matches the scale of a typical World Bank project. On the other hand, the research done to bring about these innovations on the island was largely adaptive and the development costs were correspondingly small. There was therefore a possibility for high pay-offs.

Practicum on Estimating Social Benefits and Social Costs

On return from the field trip, the small groups completed the analysis process, working with a pro forma (Figure 4) designed to serve both as a checklist of the social costs and benefits to search for and as a preliminary computational form for laying out the net benefits stream.

All projects were found to have positive rates of return, although returns to the animal-oriented projects were projected as marginal. Returns to one plant-oriented project were so great that during calculation one of the participants yelled out to the group, "We've just paid for CARDI!" The estimated benefits over 10 years of this project exceeded the costs by an amount that was greater than CARDI's budget during its operation so far.

Table 2 summarizes the lessons learned from this experience and identifies the key candidates that influence the appropriateness of action training for teaching impact-assessment skills.

Figure 4. CARDI pro forma for benefit assessment

Title: _____
(Same as on the Activity Record Sheet)

Reporter: _____

Island (or region): _____

Unit of analysis: _____
(e.g., 1 hectare, 1 farm, 1 family, 1 island, etc. — whatever is appropriate)

Social Costs

Annual (additional) social costs for one unit:*	_____
Goods and services purchased	_____
Labor (Shadow price if previously underemployed — opportunity cost + associated costs)	_____
Management	_____
Land (Shadow price if necessary)	_____
External costs (e.g., pollution)	_____
Other: _____	_____
Total	_____

Social Benefits

Annual social benefits for one unit, as shown above:*	_____
Greater production	_____
Quality improvement	_____
Change in location, time of sale	_____
Change in form (grading, processing)	_____
Cost reduction due to	_____
New variety or strain	_____
Better transportation	_____
Losses avoided	_____
Gains from mechanization	_____
Improved health	_____
Improved nutrition	_____
Savings in research, extension due to better methodology, efficiency of administration (Don't count savings if they will be accounted for above as reduced research costs.)	_____
Improved public policy	_____
External benefits	_____
Other: _____	_____
Total	_____

Net Social Benefits

Net social benefits, annually, to one unit
(total social benefits minus total social costs, from above):_____

The Benefits Stream

Potential number of units adopting _____

in _____
(Name of island, country, region)

Year	Research Costs	Estimated Number of Adopting Units	Estimated Social Benefit (adopting units x benefits per unit)**	Net Benefits When Counting Research Costs
1.	_____	_____	_____	_____
2.	_____	_____	_____	_____
3.	_____	_____	_____	_____
4.	_____	_____	_____	_____
5.	_____	_____	_____	_____
6.	_____	_____	_____	_____
7.	_____	_____	_____	_____
8.	_____	_____	_____	_____
9.	_____	_____	_____	_____
10.	_____	_____	_____	_____
11.	_____	_____	_____	_____
12.	_____	_____	_____	_____
13.	_____	_____	_____	_____
14.	_____	_____	_____	_____
15.	_____	_____	_____	_____

Note: If several islands, countries, regions, etc., are involved in adoption of the innovation and if the adoption rates over time are likely to be different in the different islands, etc., copy this page and prepare a new page for each island, etc.

*Checklist of considerations when assigning values:

- Market price — which one?
- Ignore inflation
- Shadow price possibilities
  - Underemployed labor
    - Opportunity cost
    - Associated costs
  - Price control
  - Price support
  - Controlled foreign exchange
  - External benefit
  - If there is no market
- Ignore transfer payments which include the following:
  - Taxes
  - Interest
  - Subsidies
- Do not count depreciation

**This figure is net of research costs.

Table 2. Conditions Influencing the Appropriateness of the Action-Training Methodology for Learning Impact-Assessment Skills, Based Lessons from the CARDI Dominica Workshop

Condition	Most Appropriate	Least Appropriate
Involvement of agricultural research personnel	Research professionals are joined at the workshop by executives and others responsible for the institute's long-term impact assessment.	Research professionals and ministry counterparts attend workshop without executives and other influential personnel.
Participant mix	Participants appreciate the need for demonstrating the socioeconomic impact of new technologies prior to the workshop.	Participants are primarily focused on scientific issues in their work.
Relevance of workshop materials	Training materials and examples are drawn from the actual work context of participants.	Training materials and examples are generic or drawn from other contexts.
Instructional staff	Training staff is made up of an internal and external instructional team; internal members are responsible for flow, external members are responsible for content.	Staff comprised only of external trainers; all aspects of workshop are the responsibility of external team.

Replicating the Methodology

We feel that the action-training methodology described in this article can be successfully replicated. A combination of the materials developed (including visuals, readings, programmed exercises, and benefit-assessment pro forma) and the methods described in this paper, when utilized by properly qualified trainers, should provide the basis for a successful action-training approach to impact assessment in other contexts. We invite others to use these materials and those cited in the bibliographies in developing impact-assessment training programs.

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EVALUATING AGRICULTURAL RESEARCH AND EXTENSION IN PERU

Victor G. Ganoza, George W. Norton, Carlos Pomareda,
Robert E. Evenson, and Edward Walters

Abstract

This paper examines Peru's attempt to rebuild its public agricultural research and extension (R&E) sector. A study was commissioned by the Instituto Nacional de Investigación y Promoción Agropecuaria (INIPA) to answer questions regarding whether or not it would be worthwhile to invest scarce public resources in agricultural R&E. Four major questions were addressed in the study: (1) the relative importance of research versus extension and among different commodities, (2) returns to the investment in R&E, both for individual commodities and in the aggregate, (3) the allocation of funds between research and extension for different crops and different regions, and (4) the impact of improved technology at the regional level on factor use, cropping mix, demand for credit, and income risk. This paper looked at each of these areas using congruence analysis, consumer-producer surplus analysis, analysis of yield gaps and input use, and regional linear programming analysis. The results of these analyses showed that the return to Peru's investment in R&E would be high, and would be higher still if expenditures were maintained. They also showed that a coherent and articulated set of policies on credit, market information, agroindustry, and expenditures on R&E would facilitate increases in productivity.

Introduction

During the latter part of the 1960s and throughout the following decade, Peru's agricultural sector experienced dramatic structural changes as a result of an agricultural reform process. During that period, public institutions concentrated their efforts on the implementation of agricultural reform

programs while paying little or no attention to programs designed to increase productivity (Paz Silva 1974).

By 1980, it was clear that the consequences of these, and other, structural changes in Peru's institutions had been disastrous for agriculture. Per capita production had fallen steadily since 1974. Per capita food availability had declined even more (index of food production per capita declined by 10% from 1969-71 to 1980-82). Cereal imports increased by over 130% between 1974 and 1982. By then, Peru had recognized the need to improve agricultural productivity and decided to invest substantial amounts of scarce resources, both financial and human, in the rebuilding of its agricultural research and extension (R&E) services.

It was obvious that Peru needed to do something about agriculture; the creation of the Instituto Nacional de Investigación y Promoción Agropecuaria (INIPA) in early 1981 was seen at that time as the answer to the country's needs. Under the auspices of that agency, national R&E programs in corn, rice, wheat, potatoes, and beans were initiated, along with farming systems programs for the Sierra and jungle regions. Linkages were developed with the international agricultural research centers in Mexico (CIMMYT), Colombia (CIAT), and in Peru itself (CIP), as well as with North Carolina State University and other universities in the US.

The rebuilding of an agricultural R&E institution requires continued commitment of resources to build upon previous accomplishments and to keep ahead of degeneration in varieties and evolution of pests. Therefore, this investment in agricultural research, extension, and related services should be seen in the light of Peru's fragile and austere economy; it is clear to decision makers that funds invested in agricultural R&E could have been spent elsewhere. At the same time, those directly involved with R&E need to be aware that the scarce human and financial resources at their disposal, must be invested in such a way that they address the most urgent needs and that provide measurable returns.

Within the framework of diverse competition for public funds, one must ask whether it is worthwhile to invest in R&E. While those in charge of allocating resources must know how much, where, and for how long these investments should continue; those in charge of R&E must be able to demonstrate the returns to society for its investment.

To answer these and other related questions for those in charge of allocating Peru's scarce public funds, INIPA commissioned a study to evaluate its R&E program and determine the benefits which would accrue to society from its investment in R&E.

The study was to answer four major questions, each dealing with specific areas within the R&E framework. The first question to be addressed dealt with the relative importance of the efforts between the research and extension components and between different commodities. The second, was to address the issue of returns to the investments made, both in the aggregate and for individual commodities. The third referred to the allocation of funds between research and extension for different crops and different regions. The fourth question to be addressed regarded the impacts of improved technologies on factor use, cropping mix, credit demand, and income risk at the regional level.

Each of the issues for which INIPA needed a response was addressed separately, depending on the available information regarding the problem at hand. It was decided that the first issue would be dealt with by establishing a set of positive (as opposed to normative) guidelines on how to allocate R&E expenditures. These would then be compared with what was actually done during 1981-85 by running a congruency analysis. The issue of returns to R&E investments was evaluated in an ex ante fashion using consumer-producer surplus analysis. For the allocation of efforts between research and extension for different crops, a yield-gap analysis of experimental plots was conducted to measure the scope for research and extension activities. The predicted impact of new technologies on a regional level was determined from a linear programming model constructed specifically for this purpose.

To broaden the scope of this research and for purposes of this paper, it was decided to add a fifth piece by author Pomareda which addresses the macroeconomic impact of agricultural research on Peru's economy.

Congruence Analysis and Guidelines for R&E Priority Setting

A variety of decisions on R&E allocation must be made every year. For example, what proportion of INIPA's budget should be devoted to research and what proportion should go to particular commodities (rice, corn, dairy, etc.)? Which region should be emphasized? What emphasis should be placed on farming-systems approaches? How much research resources should be devoted to adapting research from other countries versus developing new technologies? These and other decisions are influenced by multiple goals and criteria expressed both nationally and within regions in Peru.

In this component of the project, a procedure was developed to provide guidelines for allocating research resources, taking into account the above questions and multiple criteria. The first step in the procedure is to perform a set of congruence calculations that show the proportion of expenditures spent on each commodity compared to the proportion of the value of total

agricultural production represented by each commodity. The purpose of this step is not to argue that all resources should be allocated in exact proportion to the present importance of each commodity, but the congruence calculations provide a useful starting point for asking questions about why the present allocation does or does not make sense. With this in mind, a set of 20 questions that should be discussed every year during the R&E planning process was developed (Norton and Ganoza 1986). An example was provided in which congruence ratios were calculated and questions discussed for Peru.

It should be stressed that the concepts of under or over allocation based on congruence ratios assume that the only relevant criterion for allocation of R&E resources for a given commodity is the actual value of production. This is clearly only a starting point for raising questions about why the allocation does or does not make sense, and the paper by Norton and Ganoza (1986) follows these congruence calculations with a discussion of other relevant criteria.

The proportion of R&E expenditures spent on rice, corn, small grains, beans, and potatoes in the aggregate is approximately the same as the value of production of those commodities compared to total production (Table 1). A congruence ratio of 1 in Table 1 indicates exact congruence. The ratio was 1.1 for research and 1.27 for extension, reflecting the slightly greater emphasis on extension, compared to research, in Peru. However, several of the ratios for individual commodities exhibit substantial divergence from 1. More resources have been devoted to rice. By the congruence measure, corn is the closest to being correctly allocated. Potatoes have a congruence ratio greater than 1 for extension and less then 1 for research.

The high congruence ratio for cereals may result from a desire to improve producer income in the Sierra and to reduce wheat imports. The high ratio for extension activities centered on potatoes may reflect the belief that there is a backlog of new technologies ready to be extended to farmers. It may also reflect the higher costs of extension in the mountains where most potatoes are grown.

Table 1. Congruency Ratios for INIPA, 1981 to 1984

	Rice	Corn	Wheat	Beans	Potatoes	Aggregate
Research	0.893	0.908	6.228	2.086	0.792	1.102
Extension	0.847	1.119	3.269	1.553	1.559	1.268
Total	0.864	1.042	4.348	1.748	1.748	1.207

Consumer-Producer Surplus Analysis

Numerous studies have examined the impact of agricultural R&E on growth in productivity, and most analyses have indicated high rates of return to public R&E investments. The procedures used for this type of evaluation have been refined substantially over time, particularly in those studies employing a consumer-producer surplus approach. None of the previous studies, however, have considered the effects on R&E benefits of demand shifts caused by population and income changes over time. In addition, most prior studies have been ex post (i.e., they have evaluated completed R&E projects) and have ignored the effects of agricultural policies.

Corn, rice, wheat, potatoes, and beans are the most important food crops produced and consumed in Peru; however, they are grown under diverse physical and economic conditions. As a result, any attempt to evaluate R&E programs in Peru must consider the regional location, international trade situation, government pricing policies, home consumption, the type of farm for which technologies are intended, and Peruvian dietary preferences. These factors affect adoption levels for new technologies and/or the distribution of R&E benefits. In the following section, the procedures for evaluating agricultural R&E in Peru are described, and the changes required in the basic model outlined by Lindner and Jarrett (1978) and Rose (1980) to incorporate these factors are examined.

Procedure for Estimation

In order to measure the benefits likely to accrue from Peru's investments in R&E, changes in consumer and producer surplus resulting from rightward shifts — actual and expected — due to technological change were estimated.

While recognizing that consumer and producer surplus analyses have shortcomings as measures of welfare changes, the study followed previous studies of research evaluation and utilized these concepts.

The basic analytical procedure used in the analysis is shown in Figure 1 for the case where no imports or exports occur, where marketable surplus equals production, and where a perfectly competitive agricultural industry exists. Demand shifts due to population and income changes were added to the basic model. For analysis of specific commodities, the assumptions on trade and marketable surplus were relaxed. A total of four variations of this original model were constructed, depending on the commodity being analyzed.

The description of the basic model follows that detailed in Norton and Ganoza (1985) and Norton, Ganoza and Pomareda (1987). The original supply curve using traditional technology is denoted by S_0 and the demand

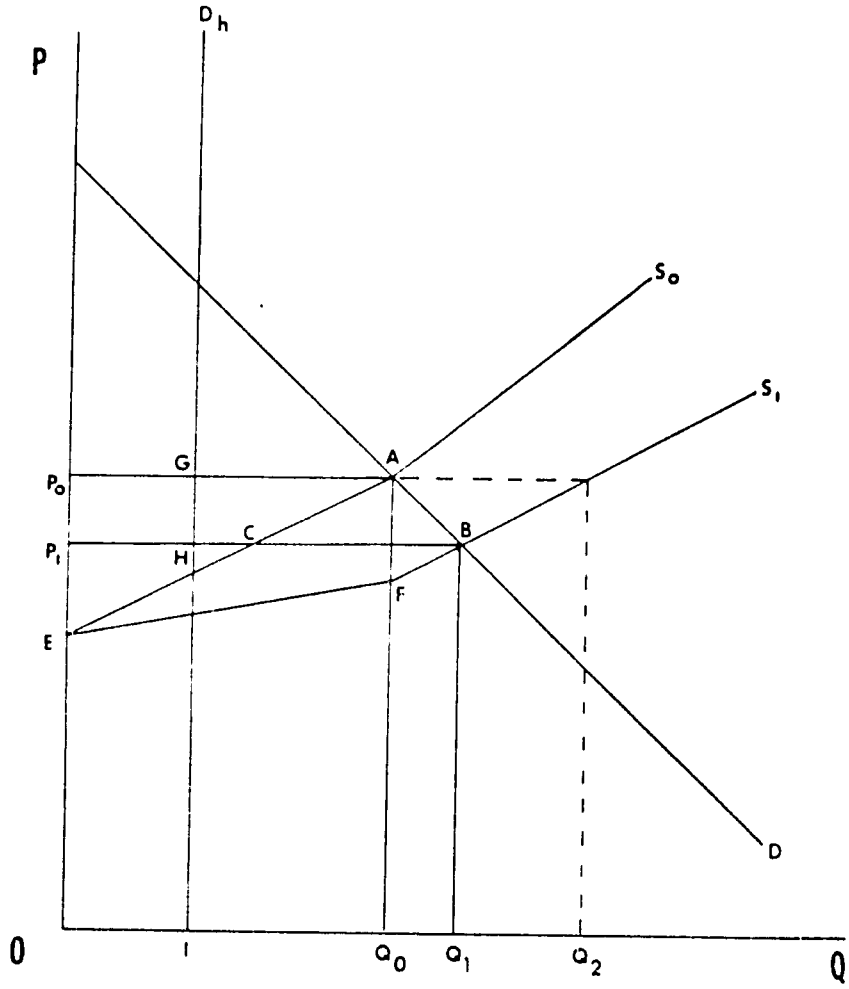

Figure 1. Benefits from research and extension

curve is indicated as D in Figure 1. The original price is P_o and the quantity supplied and demanded is Q_o. The supply curve shifts to S_1 following adoption of a new technology, resulting in the new price and quantity P_1 and Q_1. The change in consumer benefits resulting from the supply shift is represented by the area P_oABP_1, and the change in producer surplus is represented by the area $CBFE - P_oACP_1$. The net economic benefits to producers and consumers equal the sum of these changes:[1]

$$P_oABP_1 + CBFE - P_oACP_1 = ABFE$$

[1] Because of the linear supply curve assumption, a kink at F is used in Figure 1 to better approximate the area EAB (Rose 1980).

Several formulas have been developed in the literature to measure the areas in Figure 1 that represent consumer, producer, and net economic surplus. Differences depend on the specifications of the supply-and-demand curves and on the nature and measurement of the shifts. The formulas used for this study are based on equations developed by Rose (1980). Details of their derivation are presented in Norton, Ganoza and Pomareda (1987). Let *CTS* be the change in total net economic surplus, *CCS* be the change in consumer surplus, and *CPS* be the change in producer surplus. If the proportional vertical shift in the supply curve (AF/AQ_o) due to a cost reduction is represented by k, the supply elasticity is equal to e, n is the absolute value of the demand elasticity, and equilibrium prices and quantities before and after the supply shift are as described above, then:

$$CTS = 0.5\, kP_oQ_o\,(1 + Zn) \tag{1}$$

$$CCS = ZQ_oP_o\,(1 + 0.5\, Zn) \tag{2}$$

$$CPS = CTS - CCS \tag{3}$$

where:

$$Z = \frac{ke}{e + n}$$

The model of Figure 1 and of equations 1, 2, and 3 was refined to include home consumption, as in Hayami and Herdt (1977), Nguyen (1977), and Nagy (1984). This is represented by the vertical demand curve D_h of Figure 1. A shift in supply has no influence on home consumption but does affect the distribution of the net total surplus because consumers who are not producers do not gain the area P_oGHP_1 as part of their change in consumer surplus, and producers do not lose it as part of their change in producer surplus. If r is the ratio of marketable surplus to total output, then $r = \frac{IQ_o}{OQ_o}$.

The new changes in consumer and producer surplus are

$$CCS_2 = ZQ_oP_o\,(1 + 0.5\, Z_o) - Q_o\,(1 - r)\, P_oZ \tag{4}$$

$$CPS_2 = CPS + Q_o\,(1 - r)\, P_oZ \tag{5}$$

A second refinement was to include demand shifts as a result of population and income changes. The proportionate change in demand V can be approximated by the proportionate change in population plus the income elasticity of demand times the proportionate change in per capita income. Calculation

of surpluses, as described in Norton, Ganoza and Pomareda (1987), requires a two-step procedure in which the price and quantity that would have existed with a demand shift but without a supply shift are calculated first. In a second step, the formulas of equations 1, 2, and 3 (or 4 and 5 if home consumption is included), with the new initial prices (P'_o and G' in Figure 2), replace P_o and Q_o.

Further refinements include situations particular to some crops and are depicted in Figures 3 and 4. Calculations of economic surpluses under those conditions are reported in detail in Norton, Ganoza and Pomareda (1987).

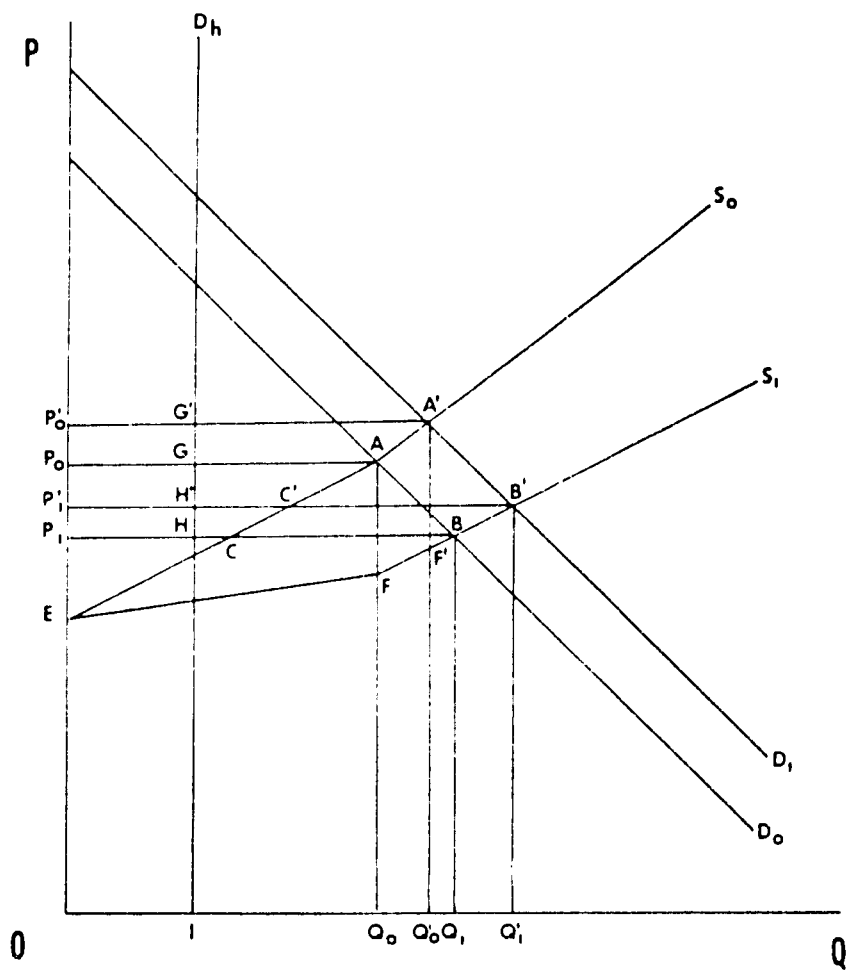

Figure 2. Benefits from research and extension with a shift in demand

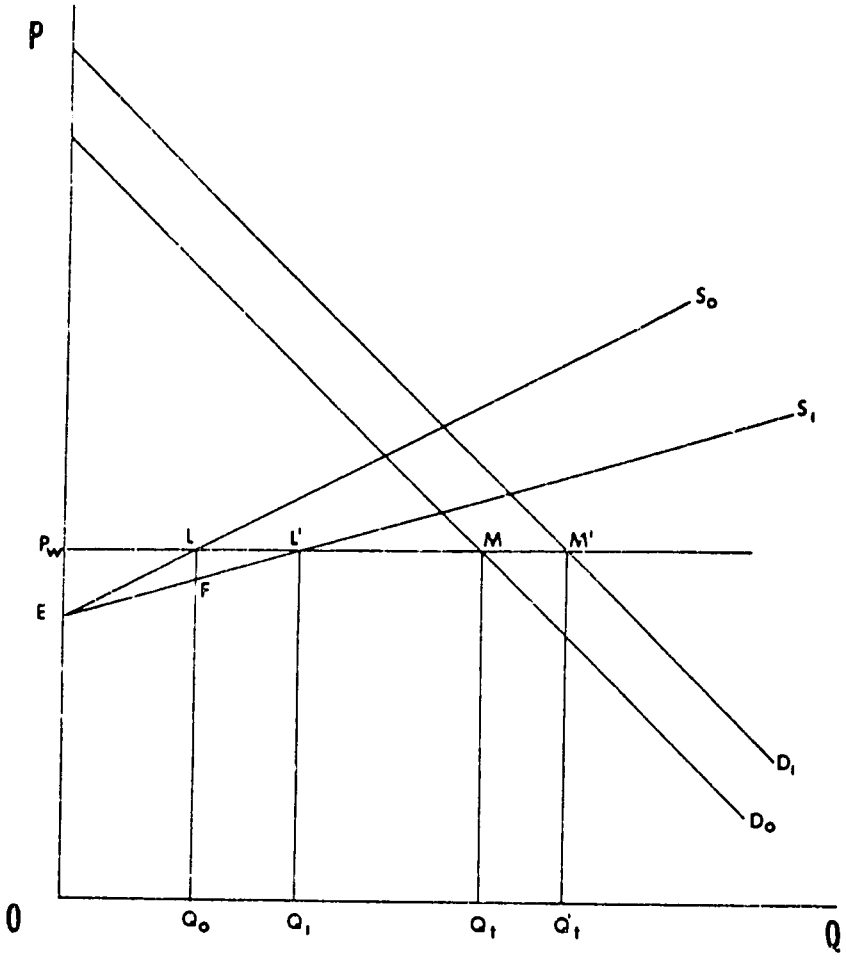

Figure 3. Benefits from research and extension with imports

Results

Analyses were run for the different crops included in INIPA's national commodity programs using the model most suited to each particular crop using a microcomputer spreadsheet program, to which formulas, data, and assumptions about elasticities and supply shifts as predicted by researchers and extensionists were incorporated (Norton and Ganoza 1985). Different scenarios were run for each crop. Total economic surplus gains minus costs of R&E were calculated along with net present values and internal rates of return under various assumptions. The results of these analyses are shown in Table 2.

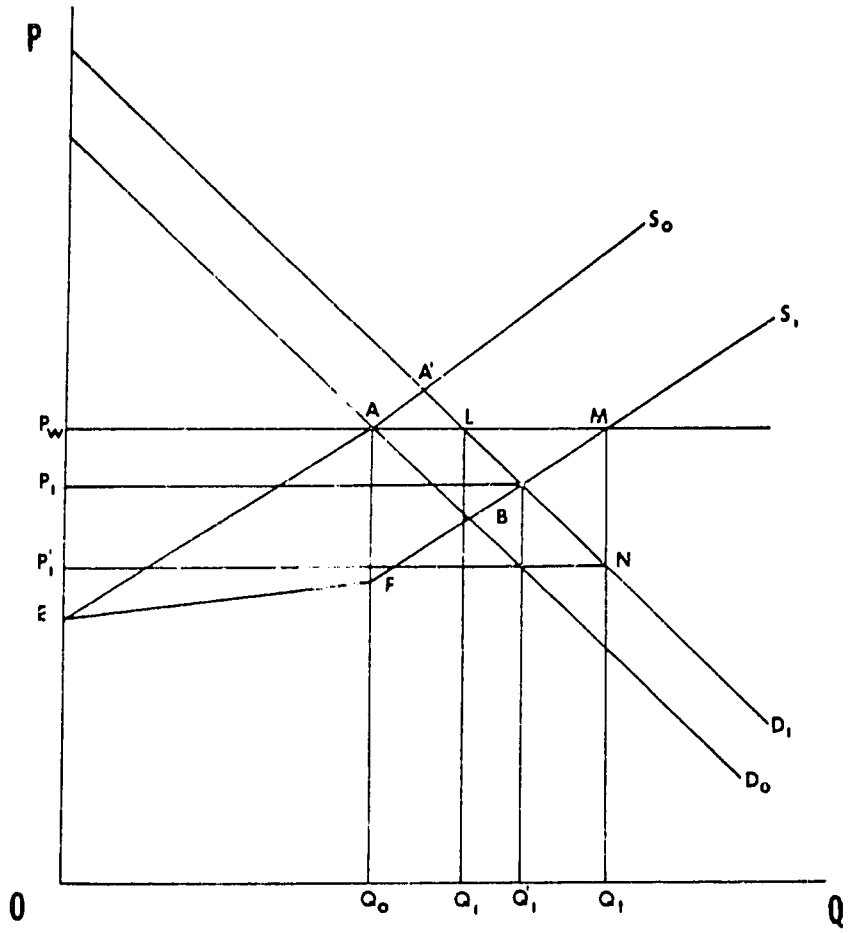

Figure 4. Benefits from research and extension with excess domestic supply

The results are quite conservative in that supply shifts are considered to be pivotal (as in Figure 1), implying that, upon adopting new technologies, low-cost producers reduce their costs less than high-cost producers. While this is a reasonable assumption, most other R&E evaluation studies have assumed a parallel supply shift, implying similar cost reductions for all suppliers. A second conservative assumption was that research expenditures would be discontinued after 1986 and extension expenditures would not be continued after 1992.

This assumption was of particular importance since at the time the study was conducted (1985), Peru's new government was contemplating the elimination of research expenditures. As can be seen from Table 2, if research

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Table 2. Summary of Internal Rates of Return to INIPA Research and Extension

	Rice*	Corn	Wheat	Beans	Potatoes	Aggregate**
Research investment from 1981 to 1986, Extension from 1981 to 1990 (percent)						
Free trade						
Pivotal shift in supply curve	17	10	18			17
Parallel shift in supply curve	35	23	28			33
No trade						
Pivotal shift in supply curve	18			14	22	
Parallel shift in supply curve	37			24	42	
Research investment from 1981 to 1992, extension from 1981 to 1996 (percent)						
Free trade						
Pivotal shift in supply curve	30	20	28			25
Parallel shift in supply curve	44	31	36			38
No trade						
Pivotal shift in supply curve				14	22	
Parallel shift in supply curve				24	42	

Source: Norton and Ganoza (1986).
Note: This summary assumes no expansion of cultivated area.
* When an expansion in cultivated area of 1.0% per year was assumed, these rates more than doubled. For example, the return to research and extension on rice for the research investment for 1981 to 1986 and for the extension investment for 1981 to 1990 changed from 17% to 48%.
** Neither free trade nor no trade.

expenditures were maintained until 1992 at the same level as in 1985 and extension expenditures were maintained until 1996, the aggregate benefits to Peru would increase by about 50% for the pivotal-shift case.

A third conservative assumption was the absence of area expansion. Area expansion for rice in the jungle is likely to occur, as is shown in the model prepared by Walters for this same study and described in a later section. An analysis allowing for an increase of one percent per year in area under rice production more than doubled the returns to rice research.

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The distribution of benefits between consumers and producers depends on assumptions about demand elasticities. Table 3 shows the percentage distribution of total net economic surplus for the different crops.

Table 3. Percent Distribution of Total Net Economic Surplus to Research and Extension at INIPA for No-Trade Scenarios

Commodity	Price Elasticity of Demand	Pivotal Supply Shift Consumer Gains	Producer Gains
Rice	$n = .76$	83	17
	$n = .39$	105	5
	$n = .27$	115	15
Potatoes	$n = .64$	72	28
	$n = .34$	88	12
	$n = .24$	95	5
Beans	$n = .61$	74	26
	$n = .31$	91	9
	$n = .21$	99	1

SOURCE: Norton, Ganoza and Pomareda (1987).
NOTE: All benefits accrue to producers for the trade scenario for rice, corn, and wheat when the price elasticity of demand (n) equals 00.

Analysis of Yield Gaps and Input Use

Agricultural extension programs attempt to reduce the productivity gap between farmers' actual management of traditional technologies and optimal management of the best available technologies. Knowledge of the size of this gap is important because if the gap is large, it implies a need for additional emphasis on extension programs. If the gap is small, it implies a need to shift the relative focus toward developing new technologies through research.

It is also important to know the effect of traditional, as compared to new, technologies on the demand for particular inputs by region. New technologies should reduce the production constraints imposed by scarce resources. For example, land and water are scarce on the coast; land labor is scarce in the jungle. New technologies should help relieve these scarcities by facilitating substitution of abundant inputs for scarce ones.

To conduct this study, data from INIPA's farm-level demonstration plots was used to evaluate the yield gaps between traditional and improved technologies and the influence of new technologies on the demand for labor, machinery, oxen, fertilizer, and chemicals.

Procedure for Estimation

Using data from the Program for Technology and Improved Seed Transfer (PTTSM) on five crops in Peru's three natural regions, yield gaps were estimated using covariant analysis (see Evenson and Gamoza 1986). Yields and input use were explained as dependent upon a series of factors for which variables were defined.

Four groups of such dummies were defined for each crop: (1) year dummies (which were used to compare all cropping seasons to the 1983-84 cropping season), (2) zone dummies, (3) variety dummies, and (4) miscellaneous dummies (which included comparisons between demonstration and validation plots,[2] and traditional technologies).

For each crop, the log of yields or input use was regressed against these groups of dummies. The coefficients obtained for the dependent variables represent the proportionate change in yields and input use due to the presence of the factor, given the following:

$$x = 0,1$$

$$dx = 1$$

$$\frac{d\,(ln\,y)}{dx_i} = \frac{1}{y}\,dy$$

Results

The results of the yield-gap analysis are shown in Table 4. These indicate that the effect of improved varieties on yields was, in general, small. Most of the "improved" varieties in the PTTSM program had been available for several years prior to the program and were already being planted where they were most suitable. This was an expected result since varieties developed by INIPA were still not available. Perhaps Peru's substantial investment in extension should have been delayed for a few years until INIPA's research component had released truly new varieties with significant advantages in terms of yields.

Most of the technologies extended by INIPA during the 1981-85 period were, of necessity, nonvarietal in nature. They were changes in input, plant density, etc. The results in Table 4 show that these nonvarietal technologies had a positive and statistically significant effect (at the 5% level) on the

[2] Demonstration plots were established in farmers' fields and supervised by the extension service. Validation plots were also farm-level plots but were supervised by research staff.

Table 4. Yield Gaps by Commodity

Commodity	Due to new varieties	Nonvarietal over traditional technology	Research field over existing technology
Rice	5%	117%	51%
Yellow corn	*n.s.**	29	18
White corn	10	24	32
Potatoes	*n.s.*	56	7
Beans	47	41	28

Source: Adapted from Evenson and Ganoza (1986).
Note: Average of improved varieties; refer to text for explanation.
**n.s.* = nonsignificant.

yields of all crops examined (except for white corn, where the effect was not significant). These effects can be considered to be a measure of the scope for the effects of extension programs. They are crude measures of the gaps between traditional practices and the best practices. Nonetheless, they permit at least an order of the scope for improvements in nonvarietal technology.

Yield impacts due to these nonvarietal technologies are not without cost since they require increased use of inputs. Their relatively small size, in combination with the general lack of yield effects due to the varieties used during the time the costs were collected (1981-84), indicate a need for additional research to develop better varieties. The PTTSM program data do not include varieties from the current corn, rice, potato, and grain legume programs. Under these programs, INIPA has begun to release new plant materials, and the results of the yield gap study confirm the need for those commodity programs.

The percentage change in the use of inputs required by new management techniques being proposed by the INIPA extension staff and refinements to these practices by the research component are shown in Table 5. It is clear from these figures that current management practices tend to be biased towards fertilizer and chemical use. However, because, of the currently low levels of input use, the absolute change in levels recommended is not as dramatic as the percentage figures appear to indicate.

Regional Linear Programming Analysis

Adoption of new technologies can affect the mix of crops produced in each region. It can also affect the demand for fertilizer, water, labor, and other inputs, as well as the level and variability of income and credit requirements. Likewise, credit and pricing policies can influence adoption of new technol-

Table 5. Percent Change in Input Requirements

	Labor		Machinery		Bullock Labor		Fertilizer		Chemicals	
	A*	B	A**	B	A	B	A	B	A	B
Rice	18	18	-33	-172	-7	-109	356	-185	428	-117
Yellow corn	5	85	-2	243	-11	-133	481	187	204	-255
White corn	-41	—	17	-36	43	70	953	41	445	-9
Potatoes	19	43	145	—	-33	117	520	-10	538	63
Beans	-13	95	73	32	17	99	414	-547	383	452

* A = Nonvarietal over traditional.
** B = Fields run by researchers over those run by extensionists.

ogies. These effects are likely to vary by region because of differences in resource bases.

Consequently, a linear programming model was developed and applied to data from two regions (Contumaza and Tarapoto) to explore the impacts of new varieties and production technologies and the effects of credit and price levels on the profitability of new technologies. The model was run for each region and maximized (minus the cost of risk) under varying levels of risk aversion subject to resource constraints. Activities in the model included the various cropping alternatives available in each region as well as activities associated with hiring labor, borrowing capital, and selling the crop. Cropping activities included both dryland and irrigated crops, disaggregated by time period and technology level.

Budgets were constructed for each production activated in the model, utilizing data from INIPA regional centers, the Agrarian Bank, and interviews with research and extension personnel. Data were also collected on labor availability, credit policies, producer prices, yields, and availability of water and extension services. Details of the model and data sources are found in Walters (1986).

Results of selected model runs are shown in Table 6. The major effects of new varieties in the Tarapoto region were to reduce the hectares devoted to tobacco, corn, and cotton from what they would have been if only traditional varieties existed. The land devoted to rice increased substantially and that devoted to soybeans increased a small amount. In the Contumaza region, barley, potatoes, and peas decreased, while rice and corn increased.

In Tarapoto, lower-risk cropping plans had less cotton and tobacco and more corn. In Contumaza, there was less rice, barley, and potatoes and more peas and corn. Lower-risk plans included approximately the same area under newly released rice varieties as high-risk plans. They also included more of

Table 6. Impacts of New Agricultural Technologies in the Contumaza and Tarapoto Regions of Peru

	Net revenue		Major changes in crop mix		Labor demand		Borrowing		Adoption of new varieties	
New Technology	Con.*	Tar.**	Con.	Tar.	Con.	Tar.	Con.	Tar.	Con.	Tar.
1. New varieties	+8%	+25%	Corn + Rice + Peas + Barley–	Tobacco – Cotton – Corn – Soybeans +	+	+	+	+		
2. Lower interest rates	+	+	0	0	0	0	+	+		0
3. Greater credit availability	+	+	Peas – Barley – Corn + Rice +	Corn + Tobacco – Cotton –	+	+	+	+	+	+
4. Lower risk			Barley– Rice– Peas + Corn + Potatoes –	Tobacco + Cotton – Corn + Rice –					Mixed	Mixed

* *Con.* = Contumaza.
** *Tar.* = Tarapoto.

the recently released corn variety, Marginal 28, in the Tarapoto area. Lower-risk plans in Contumaza had approximately the same level of new rice varieties.

New technologies resulted in a small increase in borrowing in both Tarapoto and Contumaza. Lower interest rates had little effect on the crop mix, but there was a slight increase in net returns and borrowing. Changing the amount of credit available had a much larger effect in both regions. Corn increased while tobacco and cotton decreased in Tarapoto; peas and barley decreased while rice and corn increased in Contumaza. Greater credit resulted in increased adoption of new rice and corn varieties. As a result, altering the availability of credit had a much greater effect on net returns than altering the interest rates.

Both the paper by Evenson and Ganoza (1986) and the linear programming analysis of Walters (1986) examined the impacts of new technologies on input use. These two efforts complemented each other, with the former concentrating on nonvarietal technology effects and the latter on the impacts attributable to varieties (the most recently released plant materials as well as those released during the 1970s).

Evenson and Ganoza (1986) found strong correlations between nonvarietal technology and input use. Much higher amounts of fertilizer and chemicals were required on all crops when nonvarietal technologies were implemented (Table 5). Smaller increases were needed for power inputs (human labor, machinery, and bullock labor). Given current input levels (other than labor), increases recommended with new technologies are not as dramatic as the percentage figures would lead one to believe.

Walters (1986) found a strong increase in the demand for labor in Contumaza as a result of varietal adoption. He also found an increase, albeit smaller, on the demand for labor in Tarapoto (Table 6). Demand for purchased inputs with an attendant need for borrowing also increased.

The Multiplier Effects of Technological Change in Agriculture

Some of the previous sections have shown the expected benefits of technological change for selected individual crops, individually and as an aggregate. These benefits however, are not the only ones derived from technological innovations and less evidence is available regarding the multiplier effects of such innovations.

Because the import-substitution model as it relates to development in Latin America has been exhausted and the conflict between agriculture and industrial interests is no longer manageable, there has been increasing pressure for a model for growth and equity. Some possibilities are based on current and potential linkages between agriculture and industry, linkages between agriculture and agroindustry, and backward linkages between agriculture and the factor industry for agricultural use. These provide, for most countries in the region, the potential for a new strategy that demands careful attention.

There is already some evidence that such linkages are quite strong and can be made functionally stronger if appropriate industrial, agricultural, agroindustrial, and macroeconomic policies are coherent (Piñero 1987; Pomareda 1987a). This is also supported by Mellors' (1986) proposal for the industrialization of agriculture as a means to achieve growth and equity and solve the current dichotomy.

In the case of Peru, agricultural commodities are, on the average, produced with technologies that require moderate use of modern inputs supplied by domestic industry along with a small amount of imported inputs (i.e., chemicals, engines and other selected parts, and some assembled machinery and equipment). The current state of agriculture technology varies among regions but few areas can be considered as being backward. The traditional

technologies in use are consistent with aversion to risks in production and marketing, the availability of financial resources, distortions in capital markets, and other factors such as insufficient technological information and lack of availability of improved seed. This may explain why farmers continue to use the technology they do and not those proposed by INIPA.

INIPA's technologies are, on the average, more profitable but appear riskier to the farmer. These greater risks are associated with yield instability, variability in costs, and substantially larger total costs per hectare (with, subsequently, a larger demand for credit, as was also shown by Walters [1986]). Nevertheless, if adequate policies were in place in the industrial sector (allowing supply of inputs at lower costs), if markets were to function more efficiently through better information, and if risk-management programs were available, it is likely that Peru could rapidly achieve higher rates of adoption of available, tested technologies for crop production.

This concept was tested by using a sector-level linear programming model that incorporates available technologies that are currently used for crop production, food target equations, and an agroindustrial subsector that transforms farm products into both inputs for other industries and consumer products (Pomareda 1987b). The model is rather simple, yet it is useful for evaluating the potential gains from an agricultural extension program, the goal of which is the gradual substitution of currently used technologies by those being advocated by INIPA. The model includes vectors for the production of cotton, rice, coffee, sugarcane, beans, yellow corn, white corn, potatoes, and wheat. It also allows for transformation of these vectors when required to account for agroindustrial activities.

Only beans, potatoes, and white corn could be marketed without processing. Inputs included land, labor, tractors, combines, oxen, chemical fertilizers, organic fertilizers, pesticides and fungicides, local seed, improved (certified) seed, transportation, packaging materials, technical assistance, and credit. The model was used to test alternative scenarios. For purposes of this paper, the potential impact of a 10% substitution of area planted for each crop with the best available technologies is presented. This could be achieved in one year if an aggressive extension program were undertaken. The proposed program was considered feasible by INIPA staff with only one consideration: that such a program could only be put into effect after improved seed was available in the required amounts (which would take approximately three years).

This reinforces the findings of Evenson and Ganoza (1986) that a strong effort is needed in INIPA's National Seed Production Program.

The yield gaps between the technologies that are currently being used and those that are the best available varied among crops. In the case of cotton in the coastal region, for example, the potential yield gain was 30%, but for wheat in the Sierra region, the potential yield gain was 80%. The net effects are therefore affected by the current relative importance of each crop (area planted for the crop in relation to total area planted). Table 7 summarizes the main findings in terms of agricultural production, factor use, and deducted multiplier effects.

Table 7. Response to a Program for Substitution of Ten Percent of Areas with Improved Technologies, Peru

Variable	Units	Current Situation Absolute values	10% Substitution with Improved Technology Absolute values	Percent change
Volume produced	1000 Tons			
Cotton		174.64	182.00	3.03
Rice		949.90	1,039.63	9.44
Coffee		104.38	108.62	4.06
Sugar cane		7,208.00	7,405.50	2.70
Beans		48.45	52.73	8.83
Yellow corn		585.20	633.44	8.24
White corn		226.01	248.78	10.07
Potatoes		1,257.00	1,440.20	14.56
Wheat		92.54	138.54	49.70
Total value of production	Million Intis	19,719.00	21,648.00	9.78
Net value of production		6,930.00	7,758.00	11.95
Input use total		12,789.00	13,890.00	8.60
Rural		8,041.68	8,332.30	3.61
Labor		5,313.51	5,303.09	0.00
Animal power		586.20	561.27	4.26
Organic fertilizer		12.90	12.89	0.00
Local seed		1,259.01	1,134.75	9.92
Improved seed		869.76	1,320.26	51.90
Industrial		4,742.21	5,557.92	17.07
Tractors		1,446.48	1,686.10	16.59
Combines		1,213.52	1,499.08	23.57
Chemical fertilizer		400.98	465.32	15.96
Insecticides and fungicides		966.08	1,065.60	10.25
Packing materials		36.08	40.06	11.11
Transportation		648.09	801.76	23.73
Public-sector expenditures on extension		Base	121.00	—
Public agricultural credit		3,837.00	4,167.00	8.61

A substantial increase in wheat production is noticeable. Peru now imports 92% of the total amount of wheat consumed, compared to 60% in 1970. It should also be noted that wheat is a crop of major relevance for food security in the Andean region.

In relative terms, the total value of production and increase in net income were greater than the costs of production, suggesting lower marginal costs and gains to society.

The results of factor use in the rural sector (such as the neutral employment effect due to modernizing the process of crop production) have some policy importance. Not captured, however, are the potentially positive employment effects of more agricultural industries that could be located in rural areas.

The most significant positive effects are found in the demand for industrial factors, a subject of major importance for the development of Peruvian agriculture. This calls for a set of policies that allow the increase of domestic input production. This is quite feasible given the current (1987) underutilization of plant capacity and adjustments in policies regarding exchange rates that currently favor the import of agricultural factors that could be produced domestically.

Further analysis and enrichment of the model is underway to provide more detailed information regarding multiplier effects in the agroindustrial subsector. Nevertheless, the results shown here provide wide evidence of benefits due to technological innovation that are not usually captured by partial equilibrium analysis.

Conclusions and Implications

The economic rates of return to INIPA's agricultural R&E expenditures are high. These returns are likely to be even higher in the future if present expenditures are maintained because future R&E can build on past investments. The potential for increases in yield and income by simply extending past nonvarietal technologies is relatively small, indicating the need to continue to support and extend INIPA's commodity programs. These new varietal technologies do require more labor and credit — the results strongly suggest that having enough credit available is a more important factor than the interest rate for facilitating adoption of new technologies and for increasing farm incomes.

The congruence analysis suggests a need to ask a set of hard questions every year during the process of allocating resources for R&E. Further efforts should be devoted to institutionalizing an improved R&E priority-setting process. Although this was one of the goals of the current project, the surface

was only scratched. Future research should also be directed toward additional econometric analysis of rates of return to R&E.

The regional and sectoral linear programming models suggest the need for an integrated policy approach to the matter of changes in agricultural productivity. A coherent and articulated set of policies on credit, market information, agroindustry, and R&E expenditures would facilitate the needed productivity increases in Peru's agriculture.

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THE BETTING LINE ON BEEF: EX ANTE ESTIMATES OF THE BENEFITS OF RESEARCH ON IMPROVED PASTURE FOR THE LATIN AMERICAN TROPICS

Carlos Seré and Lovell S. Jarvis

Abstract

This paper estimates that the expected returns to improved pasture research (IPR) in the Latin American tropics are very high and suggests that current research on IPR is significantly underfunded. Although increased competition from poultry may reduce future regional beef consumption, regional beef consumption and production decisions can be divorced, provided that beef surpluses can be exported. Current international beef prices are in fact biased downward due to developed-country protection. Shadow international prices, adjusted for the probability of eliminating current distortions in the long run, should be used when setting research priorities for investments that have such a long pay-out period. Such shadow international prices call for even higher expenditures on IPR. The estimates of IPR are further increased when their impact on milk as well as beef production is considered. Equity concerns suggest the need for a special effort to develop pasture technologies for areas where small farms engage in joint milk-beef production.

Introduction

The Latin American tropics contain vast areas of low fertility, acid soils which currently contribute little to agricultural production. Nonetheless, these soils have the potential to produce very large amounts of beef and milk, provided that a suitable improved pasture technology can be developed. This paper estimates the expected benefits of research on grass-legume pastures for the Latin American tropics and demonstrates, using what we believe are

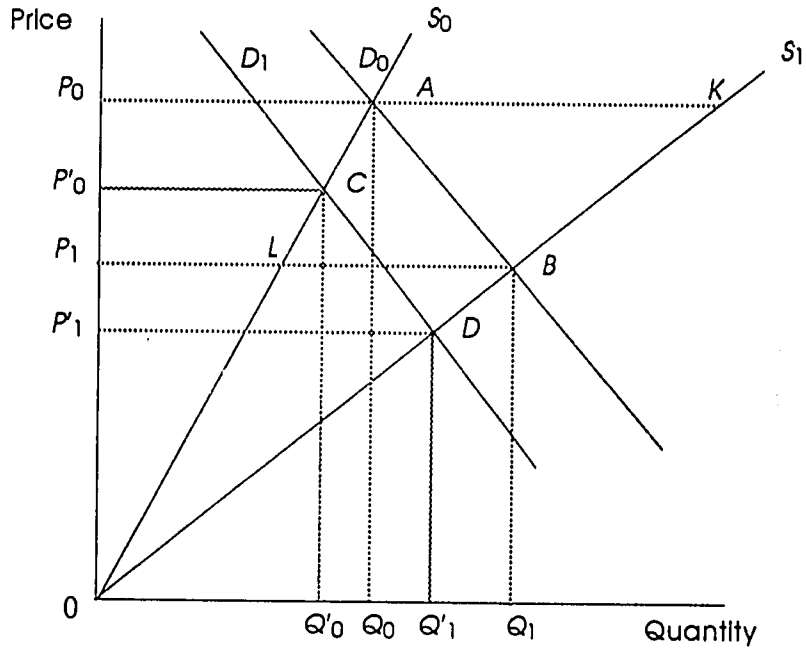
conservative assumptions, that the development of such technology should yield very large total benefits and a high return on the investment. Because Latin America is one of the few areas in the world capable of providing an increase in low-cost, pasture-based beef production, these results have relevance for the world beef market. We conclude that current research on improved pastures is significantly underfunded.

In the early 1980s, G. A. Nores (unpublished; see also CIAT 1983) predicted high returns to research on improved pasture. Nores assumed a closed economy context and took no account of the potential impact on beef demand of substitutes like poultry. Traditionally, beef has been the dominant meat in Latin American diets (Muchnik de Rubenstein and Nores 1980; Jarvis 1986; Lynam 1987). In the last two decades, however, poultry's price has fallen relative to that of beef and poultry's share in consumption has risen steadily in most countries (Rivas et al. 1987; Lynam 1987).

Poultry production in Latin America has increased at an annual rate of 7% during the past two decades, nearly three times that of beef. Poultry's price should continue to decline relative to beef, and poultry's consumption share should expand further. Within the international agricultural research community, some argue that a continuing decline in poultry's price will lead to declining demand for beef, lower beef prices, and a lower return to research on beef production. They recommend that research resources be shifted from beef itself to related areas, e.g., improved pastures, feed grains and substitutes.

In this scenario, an outward shift in poultry supply (not shown) causes an inward shift in beef demand from D_0 to D_1 (Figure 1). As a result, the benefits of improved pasture research (IPR) — which is assumed to reduce beef production costs, pivoting the beef supply curve from S_0 to S_1 — decline from $0AB$ to $0CD$, measured as the sum of producer and consumer surpluses. A significant proportion of the value of IPR is lost due to increased poultry competition.

We propose a different scenario in the belief that international trade will provide a floor to the beef price, allowing the choices between production and consumption to be divorced once exports begin (Figure 2). Thus, the benefits of IPR are $0AEF$ without increased poultry competition and $0GF$ with poultry. Even if the price of poultry declines and poultry's share of consumption rises, the price of beef will fall relatively little and could even rise if the demand for beef increases internationally. Latin American countries could thus experience a rising beef price and falling domestic beef consumption, along with higher beef production and exports — and higher poultry consumption. The availability of cheaper poultry would allow beef's price to rise with much less harm to low-income Latin American consumers. This possibility sug-



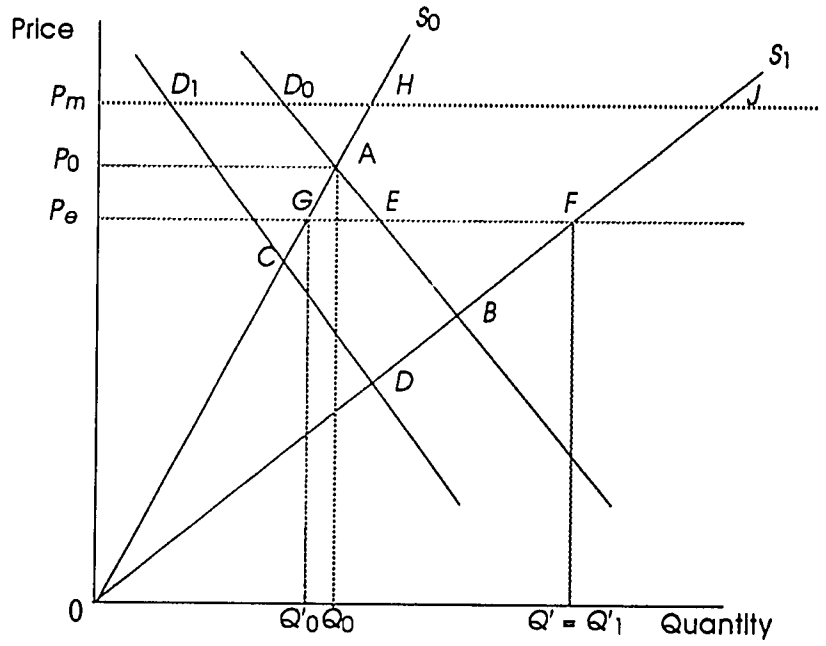
S_0 = original beef supply curve
S_1 = new beef supply curve due to research on improved pastures
D_0 = original beef demand curve
D_1 = new beef demand curve
$0AB$ = benefits of research on improved pastures *without* increased poultry production
$0CD$ = benefits of research on improved pastures *with* increased poultry production

Figure 1. Benefits from improved pasture research in a closed economy with and without increased poultry competition

gests that research into beef production does not necessarily rival research into poultry in Latin America.

The argument given above indicates that the profitability of IPR will depend heavily on the level of international beef prices, which is known to depend on the economic policies of developed-country beef producers, e.g., the United States, the EC, and Japan (see Jarvis 1986; Seré and Jarvis 1987; Alston, Edwards and Freebairn *unpublished*). Several recent studies have estimated that international beef prices would increase by 16% to 20% if protectionism in beef-importing countries were eliminated (e.g., Valdés 1987). If protectionism were eliminated or reduced in the future, the rate of return to IPR in the Latin American tropics would rise significantly.

Because IPR could have a significant impact on the distribution of income via its differential effects on countries, regions, and consumers and produc-



S_0 = original beef supply curve
S_1 = new beef supply curve due to research on improved pastures
D_0 = original beef demand curve
D_1 = new beef demand curve
$0AB$ = benefits of research on improved pastures *without* increased poultry production
$0CD$ = benefits of research on improved pastures *with* increased poultry production

Figure 2. Benefits from improved pasture research in an open economy with increased poultry competition

ers, this paper also examines some of the primary distributional issues and their implications for research policy.

Beef Production In Latin America

Latin America has a strong comparative advantage in beef production and great potential for increasing beef production through research on tropical pastures. Cattle production has been the predominant form of land use in Latin America since its colonization by the Spanish and Portuguese in the 16th century. Cattle production fitted well into the region's resource endowment: ample land, frequently with limitations on crop production; low population density; and limited infrastructure. Latin America now has approximately 318 million cattle, or 25% of the world's stock (CIAT 1987), in two major production regions. The temperate region is comprised mainly of Argentina, Chile, and Uruguay, and the tropical region is comprised of the rest of South and Central America, plus much of Mexico and the Carribean.

The two regions utilize markedly different cattle production technologies. The temperate zone is very similar to temperate regions in the developed world, from which it has been able to transfer technology, including animal breeds, germplasm for forage crops, and animal health interventions. (Productivity levels are lower in Latin America mainly because of differing relative prices for outputs and inputs.)

The tropical region has a climate less conducive to animal growth, forages are of generally poorer quality, and the threat from diseases and parasites is greater. The relatively lower amount of research on tropical livestock in developed countries makes the transfer of technology to tropical region less feasible. In addition, because the most important technological constraint is land-specific, the rate of technical progress in the beef industry in the Latin American tropics is determined primarily within Latin America itself.

During 1976-81, beef production averaged about 49 kg/head in the temperate region but only about 24 kg/head in the tropical region. Nutrition is the main factor limiting production (e.g., Wheeler 1982). The tropical region has 249 million cattle, 78% of Latin America's cattle. Fortunately, the tropical area has the potential to substantially increase its production via improved pastures.

The introduction of new forage species over a period of several hundred years has helped increase the production of tropical livestock in Latin America. To date, expansion has been based almost exclusively on grass species such as *Panicum maximum* for fertile soils and *Brachiaria decumbens* on acid soils. Nonetheless, the tropical pastures remain of significantly poorer quality than most temperate pastures. These pastures have also been attacked by diseases and pests (e.g., spittlebug), which serves to draw further attention to the high risk of operating on the very narrow genetic base of these tropical pastures.

Pasture productivity can be increased through the development and introduction of suitable legume-grass pasture mixes which make higher production per animal and per hectare possible, while also offering more persistent and stable animal nutrition. One role of the legume-grass mix is to reduce the seasonal fluctuation in pasture availability caused by the marked dry season that prevails throughout this region; thus, increasing the productivity of such lands. The improved productivity from savanna pastures can, under plausible circumstances, reduce the pressure to develop the fragile humid tropics, while also releasing more fertile land presently under pastures for more intensive crop production.

The potential payoff to pasture research has been highlighted in recent years by results obtained at several research stations. For example, at Carimagua

on the eastern plains of Colombia, the Instituto Colombiano de Agricultura (ICA) and the Centro Internacional de Agricultura Tropical (CIAT) have screened forage legumes and grasses and obtained dramatic increases in stocking rates and in production per animal. Economic analysis has shown that such technologies yield high rates of return at current prices – about 30% (Seré 1986). Scope exists for even higher profitability via reduced costs for establishing pastures (e.g., soil preparation, combined crops, and fertilizer and seed requirements), which further research is expected to bring.

Current research primarily involves the domestication of wild tropical plant species, a process implying substantial long-term investments. There is no existent stock of knowledge to permit easy development of varieties suitable for the tropics, as was the case for the first "green revolution" crops, wheat and rice. The diffusion of improved pastures, once refined, is expected to take many years. Ranchers in most areas have been cautious when adopting new pastures because pasture establishment is costly and moderately risky. Pastures can fail because of disease, pests, weather, or poor grazing management -- and management is a skill that has to be learned through doing. These problems have limited the adoption of grass-legume pastures in temperate Latin America (Jarvis 1982) and will probably affect the adoption of similar pastures in tropical areas. (However, the effort to develop a pasture technology specifical to tropical areas should yield better results than was attained in the temperate areas where pasture technology was imported without significant local adaptation.) Further, pastures can expand no faster than the livestock herd, which has its own biological limitations.

Methodology

Although an important investment is already being made in improved pasture research, we hypothesize that the high level of expected benefits would justify substantially greater research expenditures. Given the objective of documenting the orders of magnitude of the research benefits of IPR and the lack of specific information regarding many variables, we have needed to make a number of assumptions. When alternative assumptions were plausible, we chose the one that we considered most likely, but we have tried to err on the conservative side to ensure that our estimates yield a lower bound for IPR benefits. In several important cases, we show the effect of different assumptions.

The need to make assumptions regarding important parameters clearly increases the risk of error, and the problem is exacerbated by the expectation that improved pastures will achieve their full impact only after a long period. Estimating benefits in the distant future requires, in particular, estimating prices in the future under what may be supply-and-demand conditions quite

different from those prevailing today. Use of a relatively high discount rate automatically reduces but does not eliminate the impact of distant events.

IPR benefits are evaluated in terms of producer and consumer surpluses, given the estimated impact of IPR on the supply curve over a 50-year period (Figure 1). The choice of linear versus nonlinear supply-and-demand curves, as well as the choice of pivotal versus parallel shifts can have a significant impact on the estimated level of benefits and on their distribution between consumers and producers (Miller, Rosenblatt, and Hushak 1987; Duncan and Tisdell 1971; Lindner and Jarrett 1978; Norton and Davis 1981). For ease of calculation and the lack of any strong evidence to the contrary (at least for changes of the magnitude discussed here), we utilized linear supply-and-demand functions.

We allowed the supply curve to begin at the origin rather than at a positive intercept, say US$500, thus increasing the benefits to IPR. In turn, we chose a pivotal rather than a parallel *K* shift (Linder and Jarrett 1978), which reduces the benefits of IPR. As we have no strong evidence in favor of either, we selected a combination — beginning at the origin and a pivotal *K* shift — which produces intermediate benefits.

The current supply curve was estimated by drawing a line from the origin to the coordinate of current price and regional output. Initial beef production is that reported for 1985 (4.73 million tons). Because the tropical region is practically self-sufficient in beef, the initial domestic price is set at US$1625/ton carcass weight, midway between the estimated import and export prices. This yields a supply elasticity about the current price of approximately 1, a value that approximates the only available estimates for the long-run beef supply elasticity in Latin American countries: Argentina, 1.15 (Yver 1971) and Brazil, 1.56 (Lattimore and Schuh 1979).

The FOB export price chosen is US$1500/ton, roughly the current price and 5% below Uruguay's 25-year average FOB price. The CIF import price is the Uruguayan export price plus US$300/ton freight costs (Longmire and Gardiner 1984). Uruguay, a traditional Southern Cone exporter, has endemic foot-and-mouth disease (FMD). Countries free of FMD, which include Mexico and Central America, export beef at a price approximately 20% higher (Jarvis 1986), so we underestimated the benefits to IPR investments in such countries.

We assume that in the absence of IPR, any increases in regional beef demand caused by population and income growth would be just offset by increases in regional beef supply unrelated to IPR. This assumption, which permits us to measure the effect of IPR by referring to current demand-and-supply schedules, is also believed to produce a conservative estimate of IPR benefits.

In the future, without IPR, there should be a significantly greater increase in demand for regional beef than there is for supply. For the period from 1960 to 1985, beef demand in tropical Latin America increased by about 5% and supply increased about 2%. Internal prices have shown an upward trend while (net) exports have declined. Increases in beef production in recent decades have been achieved largely through expansion into unutilized savanna lands, but little additional land is available. Thus, the beef supply schedule can be expected to become significantly less elastic unless new technologies are developed.

The elasticities of regional beef demand are assumed to be -0.40 with respect to beef prices and and 0.50 with respect to poultry prices, based on recent econometric estimates for countries in the area (Rivas et al. 1987).

International prices are assumed to remain constant over 50 years. International prices for beef exported from foot-and- mouth endemic regions have had a roughly constant cycle during the period from 1955 to 1987, although prices showed an increasing trend up to 1975 and a decreasing trend thereafter, largely due to increased protection in developed country importation (Jarvis 1986). It is extremely difficult to predict whether the increased demand resulting from higher incomes and population will be offset by technical change, permitting lower cost production.

Experimental on-farm trials with legume-grass pastures of the type discussed here have been established under farmer control in the Carimagua, Colombia, region in recent years. Through adoption of the improved pastures, output has been increased from 15 kg/ha to 300 kg/ha. We assume adopting farmers will average 200 kg/ha; on average, farmers implementing new agricultural technologies achieve 66% of experimental yields (Davidson and Martin 1965). Use of 0.5 as the liveweight-to-carcass-weight conversion factor results in an expected beef production increase of 0.0925 tons of beef (carcass weight) per hectare sown to improved pastures.

Sanchez and Tergas (1979) have estimated that the Latin American tropics contain 880 million hectares of infertile acid soils, the types for which improved pasture technologies are being developed. This area contains substantial areas of humid tropics (rain forests) whose conversion to pasture is highly controversial because of possible ecological damage. We assume that no adoption of improved pastures will occur in areas of current humid forests. Were it to occur, any returns to IPR would be higher than indicated by the estimates in this paper unless offset by environmental externalities.

Fortunately, Latin America contains vast grassland areas that are already used for livestock production and where production could be increased significantly without environmental degradation, e.g., there are approxi-

mately 370 million hectares in the Cerrados and savannas, plus those areas of rainforest already being used. Approximately 10 million hectares of rainforest have already been converted to pastures, of which roughly five million hectares have degraded to the extent that they have been abandoned (Toledo 1988). These improved pasture technologies would permit the profitable recovery and long-term use of such land, increasing production and reducing current ecological damage.

We assume that this reduced area of 380 million hectares is the area potentially available for improved pastures. Of this area, we assume that a maximum of about 10% would be planted to improved pastures. Jarvis (1981) estimated that the adoption of improved grass-legume pastures in temperate Uruguay would reach a ceiling of about 11% of total pasture area in less than 20 years. The expected technical superiority of the grass-legume pastures being developed for tropical areas should result in a ceiling that exceeds this proportion.

We assume that the area planted to improved pastures is proportional to the beef price prevailing, i.e., the hectares sown at P_0 and P_1 are shown by the line segments *LB* and *AK* (Figure 1). We further assume that adoption follows a logistic process, requiring 50 years for virtual completion. Studies of other diffusion processes have revealed that highly profitable new technologies have generally been widely adopted and the entire process has been completed in 20 years or less. A longer period is reasonable in this case because specific technological packages will have to be developed for different regions and the necessary improvements in management will require time.

Finally, we calculate the present value of IPR using a 10% discount rate, where the annual benefits reflect the shift in supply achieved by IPR, gradually pivoting the supply curve from S_0 to S_1. The total shift is partitioned into small annual shifts by use of the logistic function which determines the time path of the hectares planted to improved pastures and thus the resulting incremental changes in livestock production. Each annual shift generates a set of total consumer and producer surpluses, whose sum (discounted) provides a net present value. The 10% real discount rate is believed to be high.

IPR has been underway for about a decade, and some diffusion of improved grass (and a very small amount of grass-legume pastures) has occurred as a result of past research efforts. However, no evidence is available to provide a basis for projecting any future diffusion of improved pastures if the research process were to be terminated. For that matter, neither is there any evidence regarding the incremental benefits that might be associated with each level of research investment, provided the process continues.

To compare the estimated potential benefits of IPR with associated incremental expenditures, we first converted the present value of IPR benefits into a 50-year annuity using a 10% interest rate. This calculation yielded the maximum economic annual flow of future research expenditures, assuming that past research investments are sunk costs and that no significant diffusion of improved pastures would occur without further research developments. The latter assumption led us to overestimate the returns to future IPR, provided that some diffusion would occur in any event. We doubt the error is large because few commercial packages have yet been released — past research has primarily established the technical and economic viability of the basic approach.

We then went a step further by estimating the internal rate of return to improved pasture investments, given both the stream of benefits previously calculated and also an estimated level of expenditure required to develop and then maintain such benefits. Within this framework, we also examined the effect of delaying the onset of research benefits.

Finally we examined the effect that increased competition from poultry might have on beef demand and, thereby, on the expected profitability of IPR. The price of poultry has declined at a rate of 2.8% per year during the last 25 years in Brazil, the country in which the greatest price reduction has been achieved. We projected a similar price decline for the whole region for 50 more years, allowing the price of poultry to fall to one-fourth its current level. Although such a price decline seems extreme, this assumption provided for the largest realistic negative impact from poultry competition on the returns to IPR. A cross-price elasticity of 0.5 between poultry and beef was used to estimate the associated reduction in regional beef consumption, i.e., the shift from D_0 to D_1. If the price of poultry is assumed to decline less, e.g., to one-half its current level, the effect would be to increase the consumption of beef and, thus, beef's price — at least within a closed economy — with consequently higher returns to IPR.

Economic Returns: A First Approximation

The present value of IPR was estimated for five scenarios: (1) a closed economy in which poultry has no marginal impact on beef demand, (2) an open economy otherwise identical to case 1, (3) a closed economy, in which poultry competition reduces domestic demand for beef, (4) an open economy otherwise identical to case 3, and (5) an open economy in which poultry competition reduces beef demand, but where international prices are 10% above the current level.

The estimates shown in Table 1 reflect the potentially high increases in production per hectare that can be achieved over a large geographical area. The results may be summarized as follows:

Table 1. Estimated Economic Impact of Improved Pasture Research for the Latin American Tropics

Scenario	Total Surplus	Consumer Surplus	Producer Surplus	Annual Annuity
		Billions, 1986 US$		
1. Baseline, closed economy	2.8	4.1	1.3	0.28
2. Baseline, open economy	3.1	2.3	0.7	0.31
3. Poultry reducing beef demand, closed economy	1.8	2.7	0.9	0.18
4. Poultry reducing beef demand, open economy	2.9	0.0	2.9	0.29
5. Poultry reducing beef demand, open economy, international beef price 10% above current level	3.5	0.0	3.5	0.35

Note: Net present value of 50-year benefit stream, 10% discount rate.

1. The estimated return to IPR in the Latin America tropics is high even if poultry continues to substitute for beef in domestic consumption and if no exports are possible. The returns are extremely high if beef surpluses can be exported at prices close to historical levels or above. For example, in case 1, a closed economy without competition from poultry, the estimated total surplus is US$2.8 billion. In case 3, a closed economy in which beef encounters severe competition from poultry, the total surplus remains US$1.8 billion. The latter is clearly a worst-case scenario occurring only if world markets are closed to increased beef exports from this region. In the more optimistic case 5, with beef export prices 10% higher due to a reduction in international protection of beef markets (or perhaps due to the erradication of foot-and-mouth disease within the Latin American tropics), total benefits are US$3.5 billion. Finally, in case 4 with an open economy, competition from poultry, and beef prices at current levels, the present value is US$2.9 billion.

2. Use of a 10% discount rate implies an annual annuity ranging from US$180 million to US$350 million. (These amounts are dramatically higher if lower discount rates are used.) For comparison, current expen-

ditures for research and extension in the region are estimated to be approximately US$20 million. The discrepancy between the level of current expenditures and the level that the expected benefits of IPR would apparently justify can be reconciled only if the potential benefits from IPR have previously been vastly underestimated, if policymakers have assigned a very low value (about 5%) to the probability of achieving "success" as we have defined it, or if policymakers believe that the rate of social time preference is even higher than the 10% assumed.

3. The closed-economy model consistently leads to smaller research benefits, but opening the economy has less effect on total research benefits than on its distribution between producers and consumers. As expected, IPR research will generally benefit consumers more than producers. The results shown here suggest that producers would be harmed in the closed-economy cases. Producers' gains in the open-economy cases occur relatively late in time because the first impact of increased beef production is to move the economy from self-sufficiency to the lower price export situation.

4. Competition from poultry leads to a significant reduction in research benefits in the closed economy, but it has little effect when beef trade occurs at current prices. And there is *no* effect when beef export prices are 10% higher. In the latter case, the effect of cheaper poultry is to convert the region into a net exporter before IPR has its effect on beef production, and thus all of the incremental beef production achieved is exported (Figure 2).

5. IPR benefits are high even though adoption is estimated to occur very slowly, over 50 years. The estimated internal rate of return to IPR under each of the two least optimistic scenarios, 1 and 3, exceeds 100% under the assumption that expenditures would be US$20 million during the next 10 years, plus US$5 million subsequently (Table 2). The internal rate of return remains attractive even if the commencement of adoption is postponed by another decade, beginning only after the research period has ended, and benefits are truncated at 30 years (after which improved pastures will have been planted on only about 7% of the savanna area).

The Effect of Adjustments for International Price Distortions

The results indicate the importance of adjusting for distorted international prices when setting priorities for long-term research investments, provided there is reasonable belief that such distortions will be reduced or eliminated in the future. The correct prices for use in making research decisions are the

Table 2. Estimates of Internal Rate of Return and Their Sensitivity to Lags between the Timing of Research Investments and Expected Benefits

	Case 1	Case 3
	%	%
1. Benefits start in year 1	100	100
2. Benefits start in year 6	29	24
3. Benefits start in year 11	20	15

Note: US$20,000,000 annual research expenditures during 10 years, US$5,000,000 annual maintenance expenditures thereafter, 30-year benefit stream.
Case 1: closed economy. Case 3: closed economy, poultry substitution.

border prices expected to prevail over time, given differing levels of government intervention and multiplied by the probability that such intervention will occur. Recent estimates suggest that current international prices are some 15% to 20% lower than prices would be if protection were to cease (Valdés 1987).

Developed-country importers have reduced international beef prices through a combination of import quotas and tariffs along with domestic price supports and the subsidized export of surpluses. Because of the budgetary pressures within the US and EC that have resulted from the growing costs of protection and the framework for multinational negotiations established within the Uruguay Round, we believe that it is reasonable to expect that international prices over the long run will average 10% above current levels, even if there is no other change in the underlying structure of supply and demand. Higher prices such as these would increase the expected present value of IPR to US$3.5 billion and thus justify still higher research expenditures.

Current international price distortions, through their effect on research expenditures, have the potential to seriously distort the long-term capacity for technology development and production. Within Latin America, lower border prices would discourage research and lead to a suboptimal long-term production capacity. In the developed countries, research would also be suboptimal if it were determined by current border prices. However, although border prices are lowered by protection, domestic beef prices in most developed countries are maintained at levels substantially exceeding those prevailing in international markets. It seems likely that livestock research — particularly that occurring in the private sector — may be increased by the high internal prices caused by protection, resulting in an overexpenditure on livestock research.

One question raised by this analysis is the degree to which external markets would be able to absorb increased beef exports from Latin America. Table 3 shows the increases in beef production, consumption, and exports, as well as the change in the domestic price of beef, associated with each scenario. None of the changes appears very dramatic when seen in the context of a 50-year period. Even the increase in beef exports, which is roughly equivalent to total world beef exports in 1980, seems not so large given that world beef exports grew at 5% per year from 1960 to 1980, roughly tripling in that 20-year period.

Table 3. Expected Changes in Beef Production, Consumption, and Net Exports in the Latin American Tropics and in Domestic Beef Prices from Improved Pasture Research

	Increase in Production	Increase in Consumption	Increase in Exports	Domestic Beef Price	
	%	%	*million tons*	*before*	*after*
Case 1	13	13	0	1625	1091
Case 2	55	3	2.5	1625	1500
Case 3	13	13	0	1310	800
Case 4	68	0	3.5	1500	1500
Case 5	68	0	3.7	1650	1650

If international trade in agricultural products is liberalized, the price of feed grains should also rise about 10%. This increase should make IPR more profitable. Higher prices for feed grains are unlikely to lead to significantly increased competition between crops and pastures for land use in the Latin American tropics, because soils are generally not suitable for cultivation. Regardless, there is ample area for both feed grains and pastures. However, a higher price for feed grains would increase the cost of poultry nearly proportionately in the region and internationally, stimulating both domestic and international beef demand and further raising the price of beef.

Cattle Capital as a Constraint on Pasture Adoption

Nores (unpublished) feared that the rate of adoption of improved pastures might be limited by the stock of cattle. One benefit of improved pastures is to roughly double the number of animals that can be grazed per land unit. Thus, the availability of improved pastures should have significant impact on the demand for cattle as capital goods, especially cows and young steers and heifers. If the supply of these animals is sufficiently inelastic, their prices can increase until further expansion of improved pastures is unprof-

itable. In this case, cattle rather than land or other inputs becomes the constraint on adoption.

Our calculations indicate that cattle will not be a constraint with the rate of pasture adoption assumed here. The acid soil area of the Latin American tropics currently contains about 70 million cattle. Assuming eventual establishment of improved pastures on about 38 million hectares, about 50 million additional cattle would be needed. The required annual increase should be roughly proportional to the growth shown by the logistic diffusion curve. This growth never exceeds 2.6% per year — and then only briefly. That rate is far below the biological possibility of herd growth and roughly in line with the herd increases experienced in recent decades. Thus, although there will be isolated subregions where improved pasture adoption may be constrained by lack of cattle because of a small initial cattle herd and an inability to import other animals economically (such as the Peruvian Amazon), this should not be a problem for the region as a whole.

Milk Production and IPR Benefits

Our analysis of IPR benefits has focused on beef production. Nevertheless, the adoption of improved pastures would permit an increase in the output of both milk and beef. We have no experimental data by which to estimate the benefits of increased milk production, but there are strong theoretical reasons to expect that that wherever it is profitable to produce beef and milk jointly (or simply milk), the return to IPR will be higher than that calculated when only beef is produced. This can be seen heuristically as the result of a composite milk-beef price for cattle outputs that lies above the beef price and/or a larger K shift in the joint output than for beef alone (milk production responds to improved nutrition more strongly than does beef production).

Joint production is more biologically efficient than specialized production in the tropics because it is genetically difficult to obtain an animal that can achieve high levels of specialized beef or milk production, given the significant environmental stress and relatively low-quality forage in such an area (Preston 1977). An animal with intermediate production of both milk and beef is often more profitable, though profitability also depends heavily on the costs of labor and transport. Joint production of milk and beef is most profitable for smaller farms where there is a relative abundance of labor and access to markets. Milk production also provides a regular cash income and improved family nutrition (Von Oven 1969; Jarvis 1986; Seré and Rivas 1987).

Although tropical Latin America is largely self-sufficient in milk production, importing only about 6% of its dairy products in 1980, dairy imports have risen steadily during the last two decades. Domestic milk prices in most of

the region are maintained by protection at levels well above international prices (which are depressed by subsidized exports from developed countries, particularly the EC), thereby stimulating domestic production and restricting consumption. Improved pastures provide a means by which milk production can be increased relatively cheaply to meet growing demand while also allowing domestic prices to fall.

The provision of roads and milk collection and processing facilities are important determinants of the extent to which milk could be produced in the region, but dual-purpose production is already important in many areas. Dual-purpose cows (including beef cows that are regularly milked) comprise roughly 75% of total milk cows in tropical Latin America, and though the average yield per dual-purpose cow is considerably below that of a specialized dairy cow, dual-purpose cows account for approximately 40% of total milk produced (Seré and Rivas 1987).

Equity Considerations

Most of the area that would benefit from IPR lies in several countries with especially large areas of infertile acid soils, particularly Brazil, and such countries have the greatest incentive to invest in IPR. However, most countries in the region would reap significant rewards relative to their existing livestock production, so the generic technological advances being achieved by research would be of wide benefit.

Equity concerns should encourage the development of pasture technologies suitable for use in areas with a substantial potential for milk production. While beef is produced predominantly on medium and large ranches, owned by relatively wealthy individuals, and using little labor, milk is generally produced on small farms and uses significant family and hired labor.

The benefits to consumers from IPR will depend primarily on the elasticity of the demand curves for milk and beef. If international trade cannot absorb significant beef exports, increased beef production will cause regional beef prices to decline. Although a price decline would reduce total research benefits, it would benefit consumers significantly. Beef accounts for roughly 50% of all meat throughout the region. In urban areas, where roughly two-thirds of Latin America's population now lives, beef is the most important food expenditure for every income strata, and in most countries the share of income spent on beef is highest among the poor (Muchnik de Rubenstein and Nores 1980; Jarvis 1986).

Individuals in higher income strata consume more beef and would thus gain most absolutely from a decline in beef prices, but the poor would gain as much or more, in proportion to their incomes. If domestic beef prices were

sustained by exports, consumer benefits would be lower, but the increased output caused by IPR should cause some declines in price and consumers would benefit indirectly via increased foreign exchange revenues and economic growth.

Increased milk production would be more likely to benefit consumers since the region is already a net milk importer and domestic prices would have to decline significantly before exports could begin. In regions with many small farms in particular, high population density, and adequate marketing infrastructure, milk production benefits would be skewed towards relatively lower income groups.

Because the diffusion process is likely to affect only a relatively small proportion of the total area suitable for improved pastures, improved pastures should have only a moderate impact on land values. Thus, benefits would accrue to producers who adopted and learned to manage the pastures well, but not to others. Access to intermediate-term agricultural credit and to competent technical assistance may be important to facilitate adoption. Investments in improved pastures would cost on the order of US$150/ha, and the animals needed to stock them would cost approximately US$200/ha. Although such investments should be quite profitable, many ranchers may not have sufficient internal funding to finance them, especially since the pay-out period for such investments would be five to seven years. Technical assistance would also be important to making appropriate use of the pastures since management changes would be required.

Conclusions

The estimated returns to IPR appear very attractive. Even if poultry consumption increased substantially more in the Latin American tropics, IPR would remain highly profitable. If international markets were to permit beef exports at prices close to current levels, poultry and beef production would not become significant rivals. The benefits to IPR appear higher yet when the potential to produce milk is added.

To derive our estimates we have been required to make numerous assumptions. While we believe that these assumptions were reasonable and even tended to be on the conservative side, we emphasize their importance for the results obtained. These assumptions involve judgments regarding the shape of and shifts in the supply-and-demand curves for beef — including the impact of new pasture technology, poultry technology, income and population growth, and government intervention; the rate and ultimate amount of adoption of the technology at the ranch level; and the choice of an appropriate discount rate.

We have not attempted to estimate the profitability of potential research on the production of feed grains and feed-grain substitutes like cassava for the Latin American tropics, nor have we attempted to compare whether research resources for this region — if limited — should be spent on one commodity rather than other. Our results suggest that the potential benefits of IPR justify much higher investment than is currently occurring. This should probably occur via an increase in total research expenditures rather than a shift from one commodity to another. If additional research funds are not forthcoming, agricultural research agencies would be required to ration scarce existing funds among competing uses. To make appropriate choices, estimates of the expected returns to each possible research activity in the agencies' portfolios ought to be made, but that is well beyond the scope of this paper.

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INTEGRATED EX ANTE AND EX POST IMPACT ASSESSMENT IN THE GENERATION OF AGRICULTURAL TECHNOLOGY: CASSAVA IN THE ATLANTIC COAST OF COLOMBIA

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Abstract

Initially, strategies of technology development are based on ex ante judgments of potential impact, but information that arises as the technology is developed allows the chosen strategy to be readjusted. Consequently, impact assessment and technology development become integrated in a continuous interaction between social and technical disciplines, requiring scientists with economic as well as sociological skills to become involved. Their main role starts out as identifying constraints and opportunities for new technology, estimating potential impact, and designing methods for technology dissemination. As the technology-development effort evolves, their role comes to involve the revision of potential impact and of the development strategy, based on continuous monitoring. The present paper elaborates the concept of ex post and ex ante impact integration, describes possible impact assessment methodologies, and illustrates these with data from a joint CIAT/DRI project in the Atlantic Coast of Colombia. In this project, a cassava-drying industry was established, involving changes in production technology and the introduction of new processing and marketing methods. Ex ante analysis stressed the benefits of the project to the small farmer, while the monitoring effort measured distributional benefits and readjusted the project strategy. The continuous impact assessment allowed increased goal orientation and improved distributional and total effectiveness of the project.

Introduction

Efforts aimed at generating technology can be placed into two broad categories. The first concerns research, frequently seen as a creative process in which innovative solutions (out of the reach of nonspecialized people) are identified. The second category concerns development, the collection and application of these solutions to a specific situation. Development is more of a managerial than a creative process.

A second distinction with respect to technology generation is the *ex ante* versus the *ex post* measurement of impact. Ex ante impact measurement is linked with research, in order to define the pay-offs of alternative research strategies. Ex post impact measurement comes after research and development (R&D) and reviews the effectiveness of a given R&D effort. Ex ante impact evaluation has a speculative focus; ex post impact evaluation, an historic focus. In cases where both types of analysis are applied, the time span between one and the other could be considerable.

When development projects are similar to earlier projects, ex post evaluation of the earlier projects can be useful. With an original project, such information is available only after critical decisions have been made — too late for ex ante evaluation. However, because research projects are creative in nature, and therefore, original, similar projects are not available for ex post evaluation.

The distinction between research and development implies a certain rigor in technology generation. Research comes first; development takes the research results and applies them in a specific socioeconomic context. Unfortunately, in this situation, information feedback is constrained, and the flexibility of technology generation suffers severely. This problem has been recognized widely and has given rise to the development of on-farm research methods, among other things.

The present paper presents a case study on a project with more advanced integration of research and development (outside on-farm research). Ex ante and ex post evaluation are interwoven in a simultaneous and continuous socioeconomic monitoring process. What results is a project of a genuinely mixed nature, where research and development have creative as well as managerial characteristics. A continuous flow of new information leads to stepwise reassessment of earlier decisions, such as that based on ex ante knowledge. In turn, this leads to increased goal orientation and improved distributional and total effectiveness of the project.

The project described in this paper is located in the Atlantic Coast Region of Colombia and was executed in very close collaboration with the Colombian

Integrated Rural Development (DRI) Program. It focuses on one of the most important crops in this area, cassava.

Before the actual integration of research and development and ex ante and ex post evaluation in the project can be discussed, the efforts at generating technology must be classified. This classification can then be used to forecast the potential benefits of the project, providing the basis for the managerial choices made. These forecasts and decisions are then reviewed in light of the information that became available through socioeconomic project monitoring, and subsequent project redirection is discussed. Finally, we examine the feasibility of integrated project evaluation.

Generating Crop Technology and Its Usefulness for Cassava

Following Ruttan's (1982) classification, four dimensions in the process of generating cassava technology for the Atlantic Coast Region of Colombia were considered:

1. The geography. Although the Atlantic Coast Region was predefined, the heterogeneity of the region might require further attention in generating technology. The potential impact and the effects of equity are major criteria for region selection.

2. The range of product activities from which to choose. Both authors were members of CIAT's cassava program when the research reported here was undertaken. In the present study, this dimension was predefined (it will be clear that this was justifiable).

3. The commodity system. For every commodity, there is a set of integrated production, marketing, processing, and consumption activities. One should know in which activity technological improvements will have the greatest impact and how other parts of the system may modify this impact. This dimension proved to be of critical importance for this reported study.

4. The disciplinary organization of crop technology generation. On the one hand, technology generation requires researchers (who have a plant, soil, social, or economic orientation). On the other hand, it needs technology "diffusers" from a similar range of disciplines. The separation between diffusion and research is not always very clear, but decisions on disciplinary composition as well as on research versus extension are critical for any successful effort in generating technology.

With cassava, technologically induced increases in production have often led to a decrease in farmers' incomes due to constrained markets. Projects have been located in areas without sufficient production potential. Often, the available technology (especially for processing) has not been compatible with the scale of production. And production costs have limited the possibility of expansion in stagnant areas where nothing really happened. Such experiences, among others, have indicated the need for a new, integrated vision of cassava development. The distinction made by Ruttan (1982) will be instrumental for developing this vision.

Integrated Generation of Cassava Technology in the Atlantic Coast Region of Colombia

The Atlantic Coast Region of Colombia is a tropical region, approximately 120,000 square kilometers in area, with low to moderate rainfall. Its population totals some five million souls, of whom 70% are living in urban areas. Land distribution in the region is highly skewed, a consequence of the prolonged colonization process (Spijkers 1983). More than 85% of the land is in the hands of fewer than 20% of the land owners. While large farmers mainly involve themselves in cattle production, small farmers need more intensive, but also riskier, crop activities to earn their living. Because cassava can tolerate the erratic rainfall and the intermediate fertility of the region better than other crops, it is important in small-farm agriculture.

The decision to research cassava for this region is an obvious one, given its importance in small-farm production on the one hand and human consumption on the other. Cassava is rarely grown in monoculture in the region — it is usually found in fairly complex associations with maize, maize and yams, or maize, millet, and pigeon peas. When possible, cassava farmers allocate parts of their land resources to cattle holding. The cattle serve as a risk absorber, a source of nutrition, an instrument of savings and cash flow, and a flexible labor activity. (For detailed information on how cassava development in the region has affected other crops, see Janssen [1986].)

The commodity system proved to be the most critical factor for the generation of cassava technology in the region; therefore, the ex ante forecasting focused on this dimension. Human consumption of fresh cassava is and was the major utilization of the crop. Consumption of fresh cassava is significantly lower in urban than in rural areas because it is a difficult product to market. The on-going urbanization in the country has resulted downwards pressure on cassava demand. At the same time, market channels for nontraditional food crops has improved (e.g., potatoes from the Andean region), exerting additional negative pressure on cassava demand. Also, many producers in the region market their supply very narrowly, subject to strong price

fluctuations, and where only the better roots are acceptable for sale. Initial diagnosis of the cassava system suggested that low productivity was related to price instability and deteriorating demand. Amplification and diversification of the market was most needed, rather than any improvement in productivity.

Two technological solutions to the market problem were suggested. The first involved improving cassava's marketability by packaging it in a plastic bag. The plastic bag, in combination with some harmless fungicide, inhibits physiological and microbial deterioration (Janssen and Wheatley 1985). This means that traders would have less waste from deterioration and consumers could buy larger quantities.

The second solution involved developing a drying industry that would sell cassava chips to the rapidly growing animal-feed sector. In this market, cassava prices are linked to government-supported sorghum prices, and sorghum is the main animal feed ingredient in Colombia. In this paper we will discuss forecasting for the cassava-drying industries and the ex ante evaluation of developing the drying industry versus improving the market for fresh cassava. For reasons of brevity, specific issues involved in improving the market for fresh cassava will not be discussed here.

For the ex ante forecaster, the challenge is how to integrate processing and marketing technology with production and consumption, considering the possibilities of substitution with other products or activities at different levels of the product chain. The exercise undertaken here was also complicated by the absence of reliable time series on production, consumption, and price.

Ex ante Impact Estimation Procedures

Two major questions needed to be resolved in order to obtain good forecasts on the development of cassava-drying industries. These questions concern market risk and its influence on production patterns, and the development of demand for fresh cassava versus dried cassava. Given the hypothesis that changes at one level of the product chain might have consequences at other levels, the individual answers to these questions were not considered to be sufficient. It was deemed necessary to integrate the basic mechanisms with respect to these questions in a simulation model.

Assessing Market Risk and Its Impact on Agricultural Production

Does market instability really increase the risks the farmer faces? The traditional hypothesis is that prices are high when supply is low, in which case market instability compensates price instability (Robinson 1975). How-

ever, for individual farmers, or subregions, production conditions in a specific year can differ considerably from the average. That is, aggregation to market level eliminates the variability and insecurity that a single farmer faces. Market instability, then, should be studied at the individual level.

An interview procedure with flash cards was designed to match production expectations with market expectations. Table 1 presents the average results of these interviews. It is clear that price expectations and yield expectations are not significantly related. Consequently, the coefficient of variation of income is 0.36, while the coefficient of variation of yield is 0.33. Market instability increases the farmer's income risk, and one might suspect that it also influences production decisions.

Table 1. Subjective Yield and Price Probabilities for Cassava

	Expected Yield good year (10.5 tons/ha)	Expected Yield normal year (7.3 tons/ha)	Expected Yield bad year (4.2 tons/ha)	Average probability
Expected price good market (US$ 0.114/kg)	0.07	0.12	0.17	0.36
Expected price normal market (US$ 0.83/kg)	0.16	0.14	0.07	0.37
Expected price bad market (US$ 0.055)	0.18	0.08	0.02	0.28
Average probability	0.41	0.34	0.26	
Expected price =	US$ 0.085/kg		C.V. = 0.28	
Expected yield =	7.8 tons/ha		C.V. = 0.33	
Expected income =	US$ 653/ha		C.V. = 0.36	

In the same interview procedure, it was established that market prices present too favorable an impression on cassava's profitability. This is because some 13% of cassava was not acceptable for fresh markets and because the farmer had high transportation and market arrangement costs. The cassava price obtained by the farmer was some 24% higher than the price corrected for selection and marketing costs.

The next question was to assess the effect of cassava's market instability on production. Two methods were used to answer this question, a normative

and a positive one. The positive method consisted of an elicitation approach with respect to planting behavior at contracted prices. The normative method consisted of the development of a quadratic programming (QP) model that evaluates price instability. Appendix 1 provides methodological detail on these methods, as well as their advantages and disadvantages. Table 2 summarizes the main features of these methods, along with other methodological procedures used in this paper.

Table 2. Main Features of ex ante Technology Development and Impact Assessment Methods Used in Atlantic Coast Region of Colombia

Forecasting/ Project Management Method	Sources of Information	Main Focus of Method	Methodological Complexity	Disciplinary Orientation	Expected ex ante Reliability	State of the Art of Comparable Methods
Assessment of market risk	Personal interviews	Partial supply-side analysis	High	Fare economics	Intermediate	Sophisticated for production risk Less developed for market risk
Estimation of alternative demand	Mail questionnaires	Possibility of project growth	Intermediate	Market economics	Good	Well developed (marketing)
Simulation models	Previous analytical studies	Ex ante impact comparisons	Very high	Agricultural economics	Bad in absolute sense Good in comparative sense	Methodologies available Applications rare in ex ante framework
Selection of region	Secondary data	Efficient project design	Low	Geography	Good	Simple
Estimation of institutional strength	Key informants	Expected project growth rate	High	Organizational sciences	Bad	Absent

The expected production changes per farm, resulting from the market stabilization caused by the development of a cassava-drying industry are given in Table 3. The elicitation approach forecasted larger changes in area planted than the quadratic programming approach. This is because the QP model overestimated the initial area planted. The absolute difference in area planted for the two methods is very similar, except for small farms. In any case, both methods forecast considerable allocation shifts if cassava markets

were to be stabilized through a drying industry. Both methods forecast bigger shifts for large farms, compared to small.

Table 3. Expected Effect of Price Stabilization (Occurring as a Result of Establishment of Cassava-Drying Plants) on Area Planted to Cassava

	Area Planted (ha)			
	Existing Situation	Expected Situation	Absolute Difference	Percentage Difference
Small Farm (3 ha)				
Elicitation approach	1.54	1.96	0.42	27
Quadratic programming	1.76	1.93	0.17	10
Middle-Sized Farm (8 ha)				
Elicitation approach	1.90	3.09	1.19	56
Quadratic programming	2.84	3.97	1.13	40
Large Farm (15 ha)				
Elicitation approach	2.23	3.83	1.60	72
Quadratic programming	3.08	4.25	1.17	38

The hypothesis that market problems constrain cassava production, as well as that a drying industry might increase the role of the crop in the region, was clearly supported. Effective cassava development thus became dependent on the adequate integration of marketing and production. The question became one of how to arrange access for small farmers to the large-volume animal-feed market. Small-scale natural drying plants, organized through farmers' associations appeared to be the answer, as will be discussed in more detail in the project design section of this paper.

Since quality restrictions in the animal-feed market were less stringent than in the fresh cassava market, the introduction of high-yielding, but less culinary, varieties could ease this problem. The analysis suggests that drying plants should be concentrated in areas with low-quality cassava, where large amounts are discarded and prices are low.

The forecasts show considerable production increases among all farm groups, but most with larger farmers. Also, given the need to finance drying plants, it was concluded that drying projects should be directed to the larger of the small farms and to those areas where land is available to expand production. The economic forecasts demonstrated that cassava projects could be focused on poor farmers but that some resource availability would enhance their potential. The resulting conclusion was that cassava projects are only one component of rural development. Especially if small farmers are to be effectively included in these projects, other components, such as production and processing credit, must be in place.

Since the expected benefits at this stage of the analysis were measured as a function of cassava production, farmers with the ability to increase production showed up as the most feasible target group. One can conclude that the chances of improving cassava productivity appeared good — once the spell of the unstable and nontransparent fresh cassava market was broken.

Alternative Demand Estimation and Its Integration with Fresh Cassava Demand

The previous section suggests that it is feasible to integrate small farmers in animal-feed markets. The potential benefits of such a strategy depend to a large extent on the future demand for dried cassava. An assessment of the animal-feed industry's demand for dried cassava was therefore needed.

The animal-feed industry can be considered a very rational consumer of raw materials. Quality differences of raw materials are reflected in price differences. In fact, most animal-feed industries use minimum-cost, linear programming models to decide on the purchase and utilization of raw materials.

On the basis of the procedure reported in Appendix 2, a potential national demand of some 140,000 tons of dried cassava was estimated. This equals 350,000 tons of fresh cassava, 50% of existing production. Some 30% of this demand was located in or near the Atlantic Coast Region. A price elasticity of -3.18 was found, which is a very high value, but it is in accordance with the fact that the animal-feed industry is very price sensitive.

At the same time, equations for calculating the market demand for fresh cassava for human consumption were estimated in a region-wide survey. Margin marketing behavior was determined, and coupled with final consumer demand, farm-gate demand functions were derived. Demand for dried cassava at the animal-feed factory was converted into fresh cassava equivalents at the farm gate. The different demand functions were added into a total demand function.

It appeared that the demand for dried cassava could provide an incentive for cassava production. The high price elasticity confirmed the expected price stability in this market, as long as sorghum prices were stable. Attention, therefore, turned to the development and implementation of technology for small-scale processing so that dried cassava of sufficient quality could be produced at a minimum cost to the producer.

The absorption capacity of the regional dried-cassava market appeared sufficient for rapid initial development of a drying plant. Research to reduce transport costs was only considered necessary in the intermediate term. The large potential for national demand suggested that research on the utiliza-

tion of dried cassava was not needed. Linking small farmers with the animal-feed market through small-scale drying plants appeared an excellent means to convert resource-poor peasants into entrepreneurial farmers.

One useful side benefit was the contacts established with potential purchasers. Afterwards these were consolidated in a client data base, which could be used to establish sales contacts. Impact forecasting thus had direct managerial input as well.

Integrated ex ante Forecasts of Cassava Development through Simulation Models

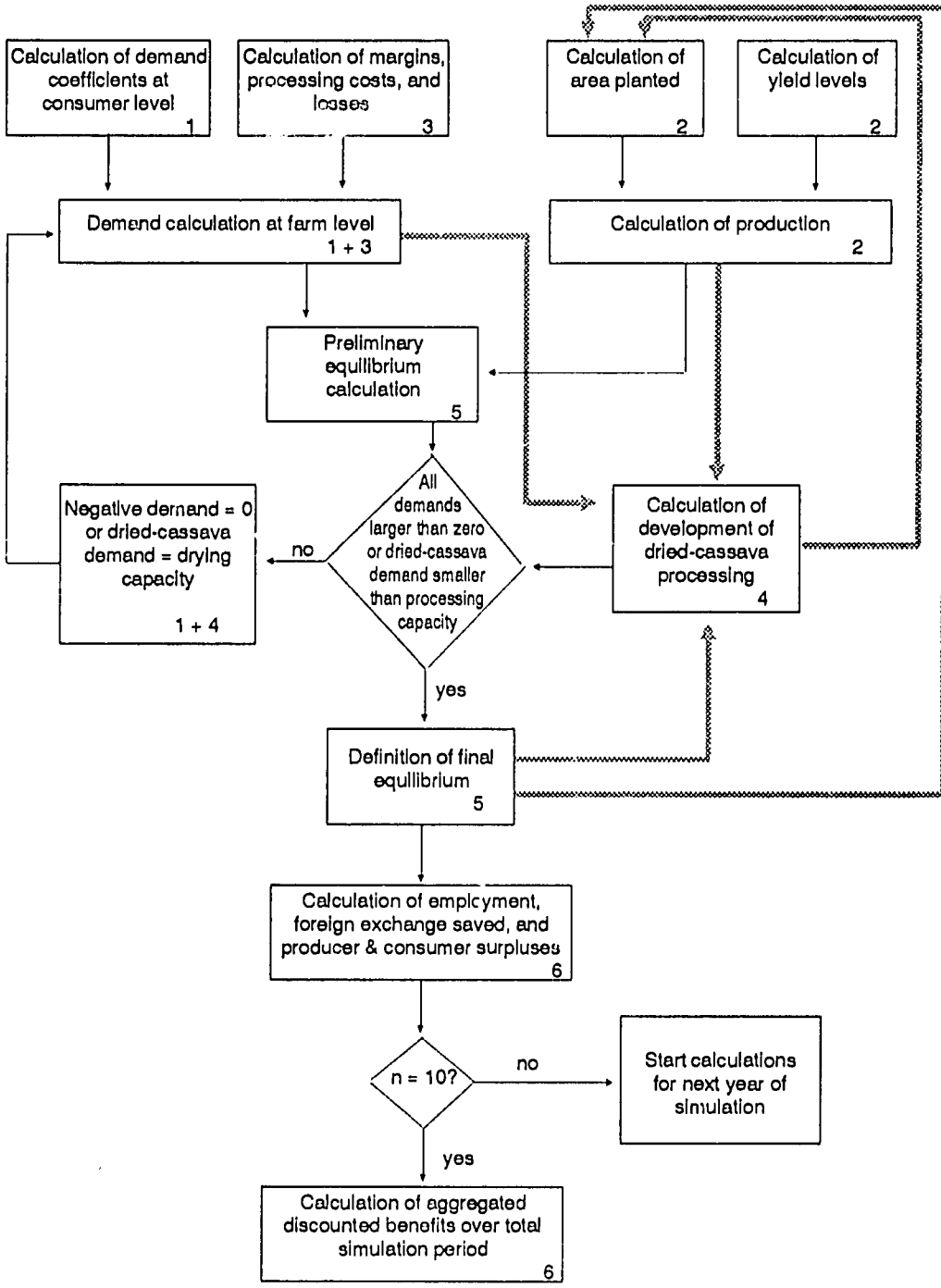
The first parts of this analysis forecasted supply and demand for a cassava-drying industry. Extensive marketing and consumption studies on fresh cassava and marketing and processing studies on dried cassava were also made (Janssen 1986) but are not reported here. While providing an insight into the mechanisms determining the *potential* of cassava development, these studies did not shed much light on the *dynamics* of that development. They provide estimates on production and consumption shifts per individual but not on overall expected developments in commodity systems. To estimate regional production and consumption shifts as well as the different benefits of cassava development, a simulation model had to be developed.

The model is recursive, with a 10-year horizon, and interprets the static results of the former analysis in a dynamic context. Demand equations include population and income growth, a distributed lag specification is chosen for cassava supply, and the development of the cassava-drying industry is endogenous to the model. A schematic presentation of the model is given in Figure 1; a brief explanation is given in Appendix 3.

The model was first used to evaluate the development of a cassava-drying industry versus the development of fresh-market storage methods, in comparison with no development of the cassava system. The model was also run at different assumptions, including expected cassava productivity, growth in the drying industry, and growth in demand for dried cassava. A summary of results is presented in Table 4.

The first outcome of the model is that without the development of economical drying or storage, the cassava industry essentially stagnates at current levels of production and consumption. The effect of the growing population is also countered by rural-urban migration and the substitution of cassava with more convenient foods.

The development of a drying industry, along with storage, significantly changes the prognosis. With a drying industry, production would increase



Notes: Solid lines indicate the effect within one year of simulation; broken lines indicate the effect from one year to the next. The influence of exogenous variables has been omitted from the diagram. Numbers at the bottom of the blocks correspond to model components as explained in the text.

Figure 1. A schematic representation of the Atlantic Coast cassava system simulation model

Table 4. Results of Simulation for the Cassava System in the Atlantic Coast Region of Colombia: Production, Consumption, and Social Benefit Parameters

	1985	A 1994	B 1994	C^1 1994	C^2 1994	C^3 1994	C^4 1994
Total production/year	480,878	497,001	551,886	666,137	682,471	698,738	678,255
Average yield (tons/ha)	6.82	7.1	7.44	8.2	8.5	8.35	8.25
Area planted (ha)							
—large farm	26,801	26,398	28,743	32,496	32,078	33,710	32,956
—medium farm	21,142	20,916	22,301	24,708	24,472	25,433	24,972
—small farm	22,502	22,344	23,076	23,699	23,583	23,983	23,821
On-farm cassava price (US$/kg)	0.085	0.076	0.088	0.082	0.81	0.85	0.85
Cassava consumption/capita (kg)							
—Urban population	29.9	21.6	39.4	21.1	21.2	21.0	21.9
—Rural population	80.6	63.7	83.3	62.2	62.6	62.7	61.5
Consumption of dried cassava (tons)	4,089	4,681	3,494	80,108	84,880	95,797	88,593
Rural employment in cassava-related work (person-years)	21,608	21,541	23,740	27,422	27,530	28,597	27,927
Producers' surplus (million US$)	n.a.	—	20.6	33.3	33.1	50.8	35.8
Consumers' surplus (million US$)	n.a.	—	40.0	-5.7	-4.3	-8.3	-6.5
Animal-feed industry surplus (million US$)	n.a.	—	-1.9	7.2	8.5	8.1	7.0
Total surplus (million US$)	n.a.	—	58.7	34.8	37.4	50.6	36.3

Note: 1985 = Situation at the start of the model.
A = No development of drying industry, no development of fresh storage (base run).
B = Technology for storage of fresh cassava successfully introduced.
C^1 = Successful development of cassava-drying industry.
C^2 = Yield increase 50% above estimated increase.
C^3 = Drying industry grows at double the expected rate.
C^4 = Demand for dried cassava grows at double the expected rate.

at 3.7% per year. Improved storage would induce a growth rate of some 1.5% per year. In both cases, the expected decline in the farm-gate price would be countered, but improved storage would have a greater impact on this. Although cassava is mainly grown by small farmers, drying would favor the larger small farmers the most. The development of a drying industry would have the greatest impact on area planted and yield than would improved storage of fresh cassava.

The impact of the development of alternative markets on traditional markets is a major point of interest. Cassava drying would slightly reduce fresh

cassava consumption, but it would almost completely generate its own supply. Improved storage of fresh cassava would firmly reverse the present trend in declining consumption.

The benefit parameters show that cassava drying would create significant rural employment as well as rural income (as measured through the producer's surplus), more so than improved storage of fresh cassava would. The technology for improved storage would generate more consumer benefits in the form of reduced consumer prices. Drying may be considered a rural strategy, while improved storage is an urban strategy.

Although total benefits in the case of storage are greater, this strategy appeared riskier and was not oriented towards redressing the structural unbalance in rural-urban development. For this reason, the development of a drying industry was given priority.

The size of the total benefits that would result from developing a cassava-drying industry were more sensitive to growth in drying capacity than to growth in either productivity or demand for dried cassava. In fact, benefits to producers are barely affected at all by differences in productivity growth; the animal-feed industry is the area that benefits most. A more rapid increase in the demand for dried cassava would mainly affect urban consumers but would not give cassava producers greater benefits.

A simulation model always responds to the assumptions on which it is constructed. Some conclusions were logical extensions of the previous analyses, such as the size of the benefits accruing to large versus small farmers from the development of a drying industry. Other conclusions, however, could not have been derived without the capacity of such a model to integrate and compare complex mechanisms at different levels of the commodity system. The overwhelming importance of building a drying plant versus developing production had not been foreseen. The impact of improved storage of fresh cassava was larger than expected and gave rise to some small-scale storage projects.

A major conclusion from the simulation was that emphasis should not be put on improved utilization of dried cassava (e.g., by nutritional research), nor on pursuing rapid increases in productivity. The greatest benefits could be gained by focusing on developing a drying industry. In more abstract terms, growth in neither productivity nor demand would be the key factor for improving the role of the crop in the region — it would be the linkage of demand with production.

The simulation model suggested that cassava's development depends on the capacity to redefine the role of the crop in the rapidly changing structure of

Colombian agriculture. Whereas for traditional rural consumers, decreases in production costs would enhance the dietary role of the crop, improvements in marketability would have the greatest impact for the growing group of urban consumers. With respect to the animal-feed industry, 20 years ago it was nonexistent, but now it could provide an opportunity for long-term growth in production and income for cassava farmers. The simulation model became the ex ante proof that the integrated analysis of the cassava commodity system could provide adequate parameters for technology design that could not be obtained in more isolated production analysis. The model also showed that crop development should not depend only on solving the technological problems of today, but even more so, must depend on the anticipation of future problems and opportunities.

Issues in the Design and Transfer of Cassava Technology

The ex ante forecasts reported in the previous section provided a considerable number of design criteria, which were especially useful in defining organizational concepts: the ownership of the cassava-drying plants, the selection of the region, and the disciplinary composition and institutional strength of the project team.

The Organizational Concept

The risk assessment of the cassava market made it clear that drying plants could stabilize markets and help increase production. Why, then, had this development not taken off by itself? Timing appeared to be one reason. The slow deterioration of the market for fresh cassava, coupled with the recent arrival of a rural development program and a rapidly growing market for animal feed, provided the conditions in the early '80s to foster the development of a cassava-drying industry in the region.

Another reason for the absence of spontaneous development was the price illusion in the market for fresh cassava, where only good-quality cassava could be sold. The availability of low-quality cassava would be a significant force in the development of a cassava-drying industry. The ability to sell commercial-quality cassava to a drying plant in years of poor market conditions for fresh produce would form a secondary force. A successful drying industry could depend on the establishment of close relationships between farmers and drying plants, and the development of small-scale drying plants appeared to be the most appropriate solution.

It was decided that a pilot drying scheme in one area would be started before development on a larger scale was stimulated. Such a pilot project would allow for technology adaptation at the processing level, could be the basis

for establishing commercial contacts, and could also help in finding locations for agronomic experiments on increasing cassava productivity. The pilot project would hopefully provide insights into previously unresearched issues. It could also serve to test the possibilities of linking small farmers with the large market for animal feed. The pilot project is expected to provide a small-scale, neutral prototype for cassava development that can be easily copied in other parts of the region.

Ownership of Drying Plants

Drying plants could be owned by private entrepreneurs, individual farmers, groups of farmers, or state organizations. State organizations were ruled out because this implied long-term government involvement and in some ways contradicted the assumption that cassava drying would be profitable

The choice between farmers and entrepreneurial ownership was based on the expected character of the drying plants, as arising from the market assessment. In their initial stages, cassava-drying plants were expected to play an important role in stabilizing the market fresh for fresh produce. This implied that in years with very high prices for fresh cassava, drying activity might be very low. In such a situation, the income from cassava processing would be rather unstable and would not offer a sufficiently secure profit to private entrepreneurs. Drying plants would allow farmers to play their market with more success by selling either in the fresh or the dried market, so ownership would be most attractively located with the cassava producer.

Nevertheless, small, individual cassava growers would not produce enough to enter the large-scale animal-feed market, nor would they have sufficient capital or credit to build their own plants. The organization of farmers in associations appeared to be the best form for obtaining a minimum processing capacity as well as sufficient credit and capital. Farmers' associations would also be able to provide the labor to run the plant from their own ranks (Bode 1986).

Region Selection

The Atlantic Coast Region is too large and diverse for an overall effort to generate technology. Once the pilot phase was passed, the selection of target regions for developing drying plants was seen as one of the first requirements for rapid initial development of the industry. The relevant part of the region is divided into four subregions, and these were taken as the basis for selection. Although the borders of these subregions do not completely reflect ecological differences, they form political boundaries for all rural development in the region and appeared to be the best reflection of the regional dimension of technology generation.

Three criteria for region selection were identified. The first two criteria, production and processing potential, defined the suitability of the region and were largely based on the outcomes of the market risk assessment and the simulation model. The third criteria, the project's impact on the selected area, attempted to maximize social pay-offs.

For each criterion, a number of determinants were fixed. The resulting decision scheme is shown in Table 5. After recollection of regional data, Table 6 resulted. The subregion of Cordoba is ranked as the best place to develop a cassava-drying industry, and Sucre is the second best. Between the two other subregions, no clear choice could be made. Equity considerations favored Bolivar, but processing feasibility favored Atlantico. The choice was left to the government officials in charge. Since scores on all determinants were known, they had all the tools for an easy decision available.

Disciplinary Composition and Institutional Strength

Plant development and market linkage appeared to be the critical factors for developing a cassava-drying industry in the region. Therefore, the initial bias in disciplinary input was towards processing, marketing, and economics. Production research was supposed to become useful only after new or improved markets for cassava had been opened. Agronomic experiments were begun, but the lag time for adoption of new technology was expected to be several years.

After the pilot phase, when the project was supposed to cover more areas in the region, institutional strength was expected to be a critical variable. It was also assumed that government institutions would assist in the formation of farmers' associations, to arrange credit and provide technical assistance in the first year of operation. Afterwards, because of the profitability of cassava drying, farmers' associations were expected to expand their operations at own initiative.

It was expected that with existing institutional resources, some 20 plants could be formed, each with the capacity to process 250 tons of dried cassava per year. Considering the autonomous expansion by older drying associations, the ability to form 20 new associations per year was considered sufficient. It was decided that the project could be developed with existing resources and did not need additional manpower.

By systematically analyzing the role of cassava in the rural economy of the Atlantic Coast Region of Colombia, it was possible to specify alternative areas for technology development and to choose between them. Ex ante project feasibility and impact estimations produced clear guidelines for conceptual structure, organizational form, and most feasible target regions,

Table 5. The Potential for Establishing Cassava-Drying Industries

Major Criteria	Defined by	Reasons	Measurement	Explanation
Production potential	Availability of land	More land is needed	Farm size	Land available to farm defines expansion potential
			Types of land tenure	Secure land tenure increases continuity of production
	Possibility of mechanization	If partial mechanization possible, production can increase	Availability of tractors	Defines access of farmers to means of mechanization
			Land topography	Defines feasibility of mechanization in the region
	Potential productivity	Alternative way to increase production, strong effects on net income	Cropping system	System must allow increases in cassava productivity
			Soil quality	Soil quality influences gains in productivity
Processing potential	Market competition for fresh cassava	Vigorous market demand = strong competition for roots	Present market access	Farmers with good market access will not be interested in development of alternative markets
			Quality of fresh cassava	Farmers with low-quality cassava face more problems in fresh market
	Length of dry season	Length of dry season limits feasibility of sun-drying	Number of dry months	Plant usage increases by 8% for each additional month of dry weather
	Institutional presence	For successful formation of farmers' associations and establishment of plants	Number of officials in the zone	Proposed development relies on institutional intervention
Impact of project on region	Importance of cassava within the region	Project benefits more people where cassava is already important	Absence of other crops; Climatic/edaphologic conditions	In some regions, cassava is the only way to earn a living in agriculture
	Present institutional support	Forgotten zones benefit more from cassava development	Historical presence of government institutions	If the region has been involved in many other projects, cassava projects will bring only marginal benefits

Table 6. Scoring Used to Define Regional Feasibility for Establishing Cassava-Drying Plants

	Atlantico	Bolivar	Sucre	Cordoba
Production potential				
Farm size	0	4	1	3
Type of land tenure	3	2	3	4
Availability of tractors	3	0	4	2
Land topography	1	0	3	3
Cropping system	3	3	1	1
Soil quality	1	2	2	3
Subtotal	2	2	3	4
Processing potential				
Access to markets for fresh cassava	1	3	2	3
Quality of fresh cassava	2	2	2	2
Length of dry season	3	1	2	2
Number of government officials	3	1	3	2
Subtotal	3	2	3	3
Impact on region				
Absence of other crops	3	2	2	1
Off-farm employment	2	2	3	4
Historical presence of government institutions	1	3	2	2
Subtotal	2	3	3	3

Note: Scores on all factors are high if the score favors developing a drying plant in the region. Scores are low if there is any obstacle to development.

as well as disciplinary composition and institutional strength. The knowledge base at the start was well developed, which allowed conscious decisions to be made and suggested a prosperous future for this effort in technology generation.

Technology management, however, does not end when the development strategies have been made. Project monitoring is the logical extension of ex ante feasibility and impact assessment studies. From a theoretical perspective, monitoring is also instrumental in reviewing the ex ante forecasting methods and their conclusions, as will be clearly shown in the next section.

Project Monitoring and Adjustment

Ex post impact assessment implies that the effect of the technology has worked its way through the economic system. Such a concept suggests that there is little analysis to be done between the ex ante and the ex post

assessments; moreover, it assumes that new technology autonomously diffuses through the crop sector along a specific path, fixed by the characteristics of the technology and the structural features of the sector.

The diffusion of new technology for cassava processing (and its impact on production technology) follows from a very different concept. First, significant technology diffusion through project management is necessary before the market is sufficiently consolidated for further autonomous diffusion. Second, key interventions, through what may be termed *social technology*, can alter the diffusion path and the resultant distribution of benefits. Third, technology transfer and initial diffusion are organized within a project framework and can easily be linked to development activities. Within this concept, ex post impact assessment becomes a continuous activity, synonymous with monitoring in the project literature, and involves the translation of the ex ante results into an actual field situation.

Thus, in the case of cassava, there is a major amplification at the stage of adaptive research and transfer, compared to other crop research programs. Adjustments to processing technology, to production technology, to technology-delivery systems, and to farmers' organizations radically extend the boundaries of adaptive investigation as currently defined by farming-systems research. These adjustments are made not just on the basis of a technology-testing activity but also on an evaluation of institutional resources, deployment of plant management, of differential production responses by farmers, and of the distribution of benefits. Monitoring is a key activity when the focus of technology transfer expands beyond production to encompass processing and farmers' organizations.

The diffusion of technologies for cassava processing and production on the Atlantic Coast of Colombia has not yet reached the autonomous growth stage. What are analyzed here are issues that have arisen in the project-monitoring phase and the degree to which they were predicted in the ex ante planning phase. Since the design and implementation of the monitoring system are still evolving, these results are only preliminary, but they do suggest the value of a continuous evaluation of the technology-transfer process.

Region Selection

Project implementation adopted a different strategy in locating processing plants from that recommended by the ex ante analysis. The project did focus on Sucre and Cordoba in developing plants (Table 7); however, Sucre superceded Cordoba, which had been given the first priority in the planning phase, because of much better institutional development and a problem in timing the harvest and drying in Cordoba. And although Sucre and Cordoba

Table 7. Change in the Number of Drying Plants, by Subregion

Subregion	Number of Drying Plants 1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	Drying area (m^2)
Cordoba	—	1	1	4	9	9	6,379
Sucre	1	3	3	7	12	12	12,252
Bolivar	—	—	—	2	3	3	1,516
Atlantico	—	1	1	3	4	4	3,000
Magdalena	—	2	2	3	4	4	4,420
Cesar	—	—	—	1	2	2	1,320
Total	1	7	7	20	34	34	28,925

had been given the two highest priorities, the project decided to set up plants in all the other subregions of the Atlantic Coast. A strategic decision was made to make the project truly regional. Plants were developed in other subregions as demonstrations of the technology and to act as catalysts for developing institutional capacity.

Nevertheless, the setting of regional targets was confirmed. Performance indicators for the plants were much higher for Sucre and Cordoba than for Bolivar and Atlantico. In the latter two subregions there was greater competition for raw supplies with the market for fresh produce, as well as more severe constraints on expansion in cassava production. This confirmed the hypothesis that some regions would have a comparative advantage in processed cassava and that this "demand" for technology would be determined by the constraints on or high costs of access to established cassava markets. Regional stratification was therefore a necessary step in developing an efficient technology-transfer system.

Farmers' Production Response

A critical hypothesis within the project was that stabilizing access to cassava markets would provide a major incentive for expanding production, through both area expansion and yield improvement. An early validation of the ex ante results was essential to project expansion, especially in defining the rate at which new plants could be established. However, the evaluation of the farmers' production response to plant establishment was not easy, as it became difficult to control for other factors affecting production response.

There was no firm basis for a sampling frame for cassava production in the region as a whole and little institutional support outside the area of influence of the plants. Production monitoring thus focused initially on farmers who sold to the plants, and a list of these farmers was developed by monitoring

the plants. This meant there was no control group. Moreover, credit, yearly price variation in cassava and competing crops, the relative incentive between being a member of a plant association or only selling to a plant, and differences in efficiency between plants all introduced alternative determinants of farmers' production response, especially since sample size often limited the ability to control for these factors. The monitoring system at this early stage suggested improvements to its own comprehensiveness, rather than providing a conclusive test of the production-response hypothesis.

The monitoring results showed that association members increased the area they planted to cassava by 17% between 1984 and 1985 and 26% between 1985 and 1986. The ex ante analysis indicated that this increase in area planted would occur principally in farms of over 8 ha with secure access to land. The monitoring results, however, suggested a different pattern. First, there was an unexpected tenancy effect. Farmers with insecure access to land made up a significant portion of the farmers' associations. They were in fact first to respond to the presence of the processing plants (Table 8), with land owners lagging somewhat behind. However, for farmers who were not members of the plant associations, then the effect was as predicted, with owners showing a more consistent response.

Table 8. Percentage Increase in Area Planted to Cassava, by Land Tenancy and Membership in a Farmers' Association

	Member of Farmers' Association		Not a Member of Farmers' Association
Land Tenancy	1984/85	1985/86	1985/86
Rental or share tenancy	36	11	−25
Land owner	12	32	29

Source: Monitoring data.

This was an important result, since it suggested that the social technology (i.e., the farmers' association) could be combined with the processing and production technology to reach the poorest and most insecure portion of the population, results that could not be incorporated into the ex ante analysis. The project design was shifted to further direct benefits to a segment of the population that had been very difficult to target.

Second, the monitoring results suggested that the principal response would come from farms where the cassava area was well below the optimum, as predicted by the ex ante model (Figure 2). The initial response in fact came from farms with apparent excess capacity and where the farmers rented

land. There was a significant lag in the response of farmers who were already growing at least 3 ha of cassava. This implied either a longer reaction time on the part of farmers who had already committed significant resources to cassava or constraints on expansion not captured in the model. This observation raised a still deeper question: How can the efficiency of plant operation be evaluated as an organizational constraint limiting the farmer's production response, compared to the case where land or labor resources formed the primary constraint?

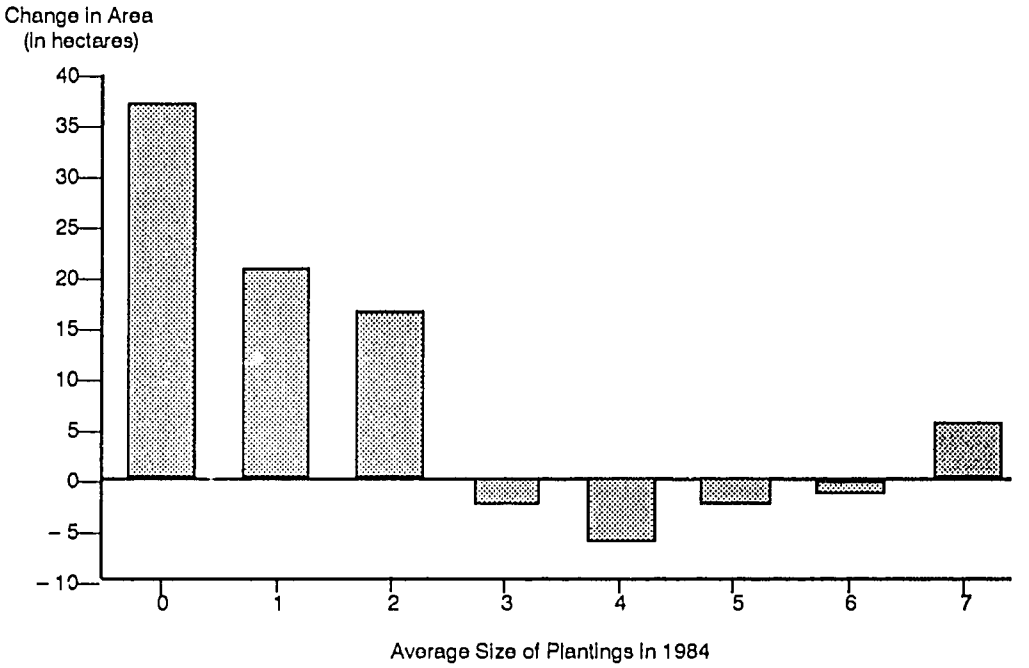


Figure 2. Atlantic Coast, Colombia: Change in area planted to cassava from 1984 to 1985, based on average area planted to cassava in 1984

Demand Assessment

Alternative demand for cassava as a raw material for animal feed was critical to project success since it would stabilize prices in the traditional cassava market, allow integration with the grain (i.e., sorghum) market, and provide significant potential for expanding production. The project did produce the desired price floor (Table 9); however, this did not prevent the market price for fresh cassava from rising in 1985-86 to the point where it acted as a constraint to the supply of raw materials. Moreover, the project appears to be having a stabilizing impact on market prices for fresh food, indicating both the effect of the supply response and the relatively marginal intervention needed to influence prices in the traditional fresh market.

Table 9. Changes in Costs and Prices during Project (1983 to 1987), in 1983 Constant Prices

	1983 Pesos/ton			
	1983/84	1984/85	1985/86	1986/87
Price of fresh roots	4,980	4,870	5,340	5,100
Total processing costs[1]	14,895	14,280	15,719	16,855
Price of dried cassava	17,180	18,220	18,770	20,454
Profit margin	2,285	3,941	3,053	3,653
Conversion rate[2]	2,530	2,380	2,430	2,570

[1] Includes costs of raw materials.
[2] Fresh roots per unit of dried cassava.

Market access, in one sense, was expanded, as is shown in the diversity of outlets utilized and the movement of dried cassava out of the region (Table 10). However, the decline in the use of dried cassava in the Atlantic Coast is indicative of the thin market in that area. Market access in the Coast was conditioned by periodic sorghum imports, both legal (through the ports) and illegal (across the border from Venezuela). Cassava became much more competitive in deficit markets inland. This gave rise more rapidly than expected to a second-generation problem: how to increase the bulk density of the product to reduce transport costs. An growing issue was when to introduce pelleting technology and what should be the organizational strategy for such an introduction. The ex ante studies oversimplified the sorghum market to a significant extent, but there was sufficient scope for adjustments so that price stabilization was in fact achieved at a relatively early stage.

Table 10. Percentage Breakdown in Sales of Dried Cassava by Market and Marketing Year

	Atlantic Coast		Interior			
Year	Cartagena	Barranquilla	Medellin	Bucaramanga	Valle	Total
						(tons)
1983/84	100.0	—	—	—	—	946
1984/85	37.5	15.8	15.6	3.2	4.9	3,006
1985/86	6.9	27.0	46.5	9.4	10.2	2,980
1986/87	9.5	14.8	67.7	6.7	1.3	3,853

Source: Monitoring data.

Market Simulation

The simulation model added a forecasting component to project planning. The project did start with the development of the dried cassava market, but only in 1987, with the achievement of market consolidation based on dried cassava, was the storage technology for fresh cassava introduced. The model

suggested that these should be complementary strategies. In practice, this has been the case so far. The initial focus of the introduction of a storage technology for fresh cassava was Atlantico, a subregion where plants for drying cassava had difficulty competing with the fresh market for the supply of raw materials. These plants ended up processing the roots that were discarded for storage. The farmers' associations also provided the organizational nucleus for the efficient introduce of storage technology at the farm level.

The project recognized that the growth of the capacity to process cassava would determine the size of the project benefits. The predicted stabilization in cassava prices was achieved in a relatively short period; however, indicators of plant efficiency suggested that the plants were operating below capacity because of an insufficient supply of raw materials. Achieving a balance between demand expansion and production response was proving difficult because of a longer lag time than was predicted in the model. Another complicating factor was that the principal production response was coming from renters and the project was driving up the rental price of land.

Moreover, the relatively larger farmers (who farmed between 8 and 20 ha) were not as quick to respond. Their constraint appeared to be access to the rental machinery market, especially since a boom in the local cotton market was monopolizing tractors for large-farm land preparation. In two cases, however, the farmers' associations were so successful in managing dried cassava processing that they were able to purchase their own tractor, through a credit line. Changes in commodity markets were thus inducing changes in factor markets, an issue which was not incorporated in the simulation model, apart from a calculation of the increase in labor use. There has been pressure by farmers for a similar credit line for land purchases, but this has so far been resisted by local credit institutions. Nevertheless, the economic and organizational preconditions for the success of such a credit line are in now place.

The ex ante model demonstrated that there was significant growth potential in an integrated cassava project. The great utility of ex ante impact studies lies in just such a diagnosis. However, the leap from potential to realized increases in cassava production and utilization is still a large one, even with a model as detailed as this one. Such detail is only captured in partial equilibrium approaches, which must often exclude interactions with other output and factor markets. Predetermining which substitution or factor market effects will be significant is difficult and depends heavily on prior knowledge.

However, the leap between potential and actual interactions goes beyond just defining the structural limits of the model. First, it would be useful to

have the probability of success factored into the model, but it is difficult (perhaps impossible) to identify the key variables that define success, much less to attach a probability to them. Moreover, some probability distributions will be conditional to others. Second, institutional support was the key to project implementation, and it is difficult to see how institutional requirements could be forecast, much less the extent to which existing institutions pose a constraint or are amenable to modification. Third, the farmers' associations were probably the key factors in the successful transfer of the technology to this socioeconomic stratum. The associations proved to be the pivotal organizational concept that gave the project flexibility in adapting to unforeseen problems or constraints. Such a role was not predicted, although it was identified early in the project and then utilized in its expansion. All of this points to the fact that technology transfer in developing countries is very much an under-researched area.

Conclusions

The integrated ex ante and ex post evaluation of the generation of cassava technology in the Atlantic Coast Region of Colombia strongly improved the creativity, focus, and goal orientation of the project. It emphasizes that agricultural technology does not necessarily have to be production oriented to improve the overall efficiency of a commodity system. It has helped rebalance the disciplinary composition of the project, define target areas, and refine the bias towards small farmers. The procedure, however, is costly in the use of project analysts. This last section will try to derive some general conclusions on the feasibility of these methods in other circumstances.

A first conclusion should be on the usefulness of the ex ante-ex post evaluation for the R&D planning of CIAT's cassava program. Understanding the supply-demand linkages has helped focus research on utilization. It has also given rise to an extensive, Latin America-wide study on ex ante prospects for cassava demand and on CIAT's potential to link its research to these prospects. In addition, it has proved critical for the development of other integrated cassava projects, which are located in Panama, Ecuador, and Mexico.

The conclusions on organizational aspects and farmer involvement have particular significance. Initially, the cassava program thought that research on processing and production would be sufficient, but now the program is more aware of the need for social technology. This is especially true with respect to the question of scale adaptation in production-market linkages (e.g., from small farmers through associative drying plants to the large-scale animal-feed industry), where appropriate organizational arrangements have proven their worth. The lack of ex ante assessments of organizational

arrangements only serves to reinforce the importance of early monitoring in integrated cassava projects.

A second conclusion should be made with respect to the methods applied in the ex ante phase of the analysis. These methods originated mainly in the field of economics. This has provided a number of very valuable conclusions, e.g., on area planted and market stabilization. However, it has failed to predict other important developments. Small farmers appear to be more motivated to join cassava-drying associations because they hope to win more by organizing themselves. In a similar way, the progress of the drying industry was not assessed well because the motivation of government programs to pursue this development had not been judged correctly.

In the project design presented in this paper, forecasting was done by economists alone, and monitoring was done by economists, anthropologists, and organizational scientists. For further refinement of project evaluation and planning methods, it is essential that anthropologists and organizational scientists be included in the traditionally economic domain of forecasting. Such a move would initially make their work more speculative and their conclusions riskier, but later on it would improve applicability and disciplinary strength. The ex ante evaluation is riskier and more difficult than the ex post one, but it also provides a greater challenge and a higher pay-off if correctly applied.

Some remarks should be made with respect to the degree of complexity that can be handled within a technology-generation project. The present paper deals with a relatively small-scale effort, one that is location- and crop-specific. Issues at different levels of the product channel were studied, and although the study is of an applied nature, rather elaborate data manipulation was needed. Still, most of the study's conclusions have had to be drawn within a partial equilibrium framework, one that can be derived from the simulation model and from the problems involved in monitoring production.

More comprehensive analytical methods could be developed, but they might well loose their versatility as a means of forecasting. or their results may become available too late to influence major decisions. A structure that might theoretically be the most advanced solution and one that could still have sufficient applicability, might be one in which the detailed analysis and modeling of a specific commodity system could be linked with an aggregate general equilibrium model and iteratively corrected with new findings.

Ex ante and ex post evaluation should thus try to identify the project components that are most critical for successful technology generation and application. These components should then be the focus of the analysis and would lead to rapid redirection of the planned strategy. The definition of

precise hypotheses on technology generation becomes crucial to efficient and flexible resource use. Intimate knowledge of socioeconomic conditions is needed to define these hypotheses, and requires that the analysts involved have the most up-to-date knowledge and experience possible.

With respect to project design, even as simple an effort at generating technology as that described in the present paper (which was for a single crop in a single region) requires complex analysis and integration of numerous components. This tends to suggest that efforts at generating technology should limit their scope. Technology generation that depends on components from many different crops or many different levels in the commodity system might be too complex to be manageable or too diluted to be effective.

One last conclusion is on the character of technology generation in agriculture. Ruttan (1977) has made it clear that technology generation is not an exogenous process. He writes that understanding the needs of farmers and society leads to a specific allocation of research resources. This allocation, in turn, influences the speed of technology generation. The present paper supports these conclusions but would take them even further. Technology generation is not only induced by the allocation of resources for research, but also by market forces. Technology generation reacts to demand pressure as supply does. Absence of demand or obscured demand (by inefficient market channels or rigid quality criteria) reduces the momentum among farmers to search for and test technological alternatives. Market instability reduces the inclination to experiment or even to introduce new technology. Successful technology generation is intrinsically linked with the existence of promising, expandable markets, especially where the concern for small-farm income is dominant. Where traditional markets are stable or deteriorating, market development, although speculative and risky, should have priority over the generation of production technology.

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Appendix 1
Positive and normative procedures used to assess the impact of market risk and their advantages and disadvantages

1. *The positive procedure*

Definitions:

AMR = Area planted at the existing price expectation

AWR = Area planted if the present price had been guaranteed

ADM = Difference between *AMR* and *AWR* because of elimination of price variability

E(P) = Expected cassava price

PR = Subjective cassava price variance

YR = Subjective cassava yield variance

COV = Subjective covariance between yields and prices

OTH = Other factors that influence area planted

A simple function to express area planted could be as follows:

$$AMR = a + b*PR + c*YR + d*COV + [e + f*PR + g*YR + h*COV]*E(P) + i*OTH \quad (1)$$

This equation assumes that the area planted has a linear dependence on price and other factors. The income variance is divided into a yield variance, a price variance, and a covariance component. The squared covariance component has been left out, following Hazell (1982). The variance components affect the intercept (through the first four terms) as well as the slope (through the terms within brackets).

The function to express area planted at contracted prices would be as follows:

$$AWR = a + c*YR + [e + g*YR]*E(P) + i*OTH \quad (2)$$

Now the price variance term has been eliminated. Since there is no price variance, covariance terms disappear as well.

For each farmer, one point at the original supply curve 1 was known because price expectations and area planted had been asked. Supply curve 2 was estimated by means of the elicitation procedure in which farmers were asked about their planting behavior at guaranteed prices.

Now equation 2 can be subtracted from equation 1. This gives

$$ADM = b*PR + d*COV + [f*PR + h*COV]*E(P) \tag{3}$$

This equation expresses the difference in area planted for an expected price versus a contracted price, which is the impact of price uncertainty on planting decisions. Within a cross-sectional framework, parameters b and d (that shift the intercept) and f and h (that shift the slope) can be estimated. Knowledge of these parameters allows estimations of the impact of incomplete price stabilization on planting behavior by solving equation 3 for the observed differences.

2. *The normative procedure*

The normative procedure to estimate the impact of market risk consists of the development of a quadratic programming model:

$$\text{Maximize} \quad E(u) = r'x + \tfrac{1}{2} L x'Qx \tag{4}$$

$$\text{subject to:} \quad Ax \quad b \tag{5}$$

$$x, L \quad O \tag{6}$$

where

r = a vector that represents income values of different farm activities

x = the vector that represents the level of these activities

Q = the variance-covariance matrix of the income values

A = the matrix of technical coefficients

b = a vector that describes resource availability

L = a scalar that weighs risk aversion versus expected income maximization

This model was specified for one of the major cassava producing areas of the region.

Production of dried cassava would provide an outlet for cassava that is currently discarded and would allow a floor price in case prices in the fresh cassava market plunge. To calculate the effect on the expected price and on the price variance, the cassava price to be paid by the drying industries was imputed for presently discarded cassava. The drying-industry price was also imputed for those points in the fresh market price probability function where fresh cassava prices are below drying-industry prices. In this way price expectations and variances with and without drying industries were generated.

The effect of incomplete price stabilization can be estimated by running the Quadratic Programming (QP) model for the different combinations of price expectations and variances.

3. *Advantages and disadvantages of market risk assessment procedures*

The QP model provides an understanding of how farm organizations could change because of improved cassava market perspectives. It indicates how supplies of other products change and evaluates technological changes in cassava production by including alternative production technologies in the activities matrix. The elicitation approach has the advantage that it does not involve an estimation of the degree of risk aversion.

A problem encountered with both methods is that they are not sufficiently region specific. The elicitation analysis needs cross-sectional data for to estimate supply curves. It uses the variability in the data to calculate an overall supply curve, but it cannot use this again to estimate supply curve differences per subregion. Data collection for the QP model is time-consuming and costly and could not be justified for the different subregions.

Appendix 2
The procedure used to estimate dried cassava demand

Dried cassava is comparable or slightly superior to sorghum with respect to caloric content, but it is quite inferior in protein content. A rough guideline would be that one ton of dried cassava plus 0.2 tons of soya would replace 1.2 tons of sorghum. This results in the following price equation:

$$PCCS = 1.2*PSOR - 0.2*PSOY \quad (7)$$

where

PCCS = Price at which dried cassava competes with sorghum

PSOR = Price of sorghum per ton

PSOY = Price of soya per ton

Nevertheless QP models calculate a shadow price for cassava of around 80% of the price of sorghum in chicken feed but close to 90% in pig feed. The willingness to pay for cassava depends on the diets produced by the manufacturer and their protein content. Cassava would first enter those diets where its shadow price relative to sorghum is highest.

This implies that an ordinary demand curve for dried cassava can be estimated. A questionnaire was sent to the animal-feed industry to estimate demand at three different price levels. This produced the slope for a dried-cassava demand curve. Since dried-cassava demand is also determined by its relative price with respect to sorghum, the slope coefficient was related to the difference between the real price of dried cassava and the price at which cassava would be competitive with sorghum, as determined in equation 7. The final demand equation for dried cassava had the following structure:

$$QCAS = a - b*(PCAS - PCCS) \quad (8)$$

Where:

QCAS = Demand for dried cassava

PCAS = Price of dried cassava per ton

PCCS = Price per ton at which dried cassava competes with sorghum

Appendix 3
A brief description of the simulation model used to forecast cassava development in the Atlantic Coast Region

The model consists of six components (for more detailed information, see Janssen 1986: 198-223).

The first component is the consumption component. Equations for fresh cassava demand are developed for different urbanization strata, an equation for dried cassava demand is included and some secondary demand components are distinguished. Shift factors are included in the fresh cassava demand functions to simulate successful introduction of storage technology. Dried cassava demand is modeled as described above. Demand equations are linear.

The second component is about cassava production. Distributed lag functions are estimated for area planted, as well as for yield. Production is then defined as yield times area. Area and yield functions are shifted upwards for that part of the region where drying plants have stabilized market perspectives. Yields are random in nature.

The third component examines marketing and processing. Marketing margins for different urban strata are determined on the basis of farm-gate prices. Shift factors are included to express the potential margin reduction if technology for the successful storage of fresh cassava is introduced. The costs of processing and marketing dried cassava are modeled.

The fourth component examines the development of the drying industry. This is made endogenous with respect to existing drying capacity, market prices for fresh cassava, potential prices for dried cassava, and profits realized from drying. This component feeds directly back to the production component by defining the part of the region where drying plants have been built and market perspectives have stabilized.

The fifth component defines equilibrium conditions for the cassava system in the region.

The sixth component calculates potential project benefits. Four types of benefits are distinguished: foreign exchange saved by consuming dried cassava instead of sorghum; employment in the cassava sector, in urban as well as rural areas; the discounted 10-year producer surplus per farm size group; the discounted 10-year consumer surplus for various types of rural and urban consumers and for the drying industry. By means of the project's

benefit parameters, the planned cassava development can be evaluated with respect to the overall objectives of agricultural policy.

The model can be written as 45 condensed equations but involves the balancing of some 90 behavioral relations per year of simulation. The model was written in Fortran. To facilitate its use, a panel was designed to set the values of the most important parameters. Since the model has a stochastic nature, 25 runs were made for each modeled situation.