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 Technology Management Workshop, 6-8 July 1988, Rutgers University, New Jersey, USA

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International Service for National Agricultural Research

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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.

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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

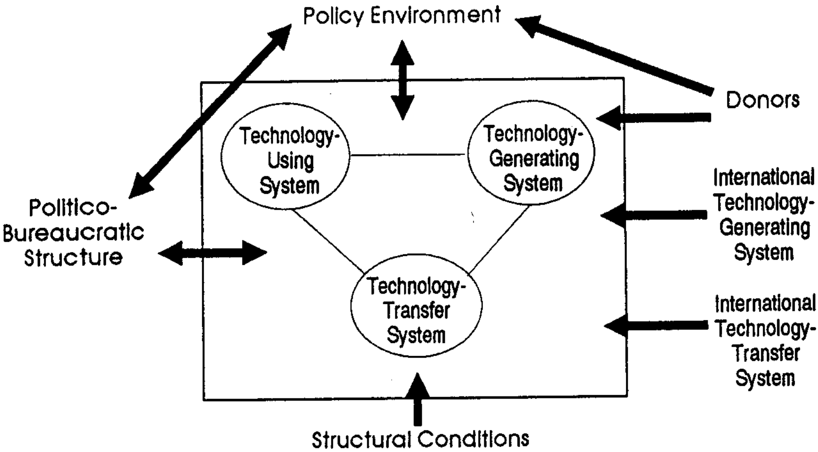
The need to look at the entire technology management system stems from the fact that policymakers are not interested in research per se; they are only interested in the technology that research can put at the disposal of farmers. This is especially true when one recognizes that future agricultural development 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;

- 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

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 germ-plasm 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 Panama'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.

References

Arab Organization for Agricultural Development and ISNAR. 1988. *The agricultural technology management system in the Sudan: Report on ATMS in the Sudan.* The Hague: ISNAR.

Churchman, C. W. 1979. *The systems approach.* New York, NY: Dell.

Elliott, H. 1987. The use of events analysis in evaluating national research systems. In *Policy for agricultural research*, eds. V. W. Ruttan and C. E. Pray. Boulder: Westview Press.

Elliott, H., R. Hertford, J. Lyman-Snow and E. Trigo. 1985. Identifying opportunities to improve agricultural technology management systems in Latin America: A methodology and test case. New Brunswick: Rutgers University.

ISNAR. 1987. Working to strengthen national agricultural research systems: ISNAR and its strategy. The Hague: ISNAR.

Kast, F. E. and J. E. Rosenzweig. 1985. *Organization and management: a systems and contingency approach*. New York: McGraw-Hill.

Marcotte, P. 1988. Personal communication.

Rocheteau, G., P. Bennell, D. McLean and H. Elliott. 1988. Organizational, financial and human resource issues facing West African agricultural research systems. ISNAR Working Paper No. 9. The Hague: ISNAR.