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ABSTRACT

The International Program for Agricultural Knowledge Systems (INTERPAKS) research team is developing a descriptive and analytic framework to examine and assess agricultural technology systems. The first part of the framework is an inductive methodology that organizes data collection and orders data for comparison between countries. It requires and allows for adaptations to the realities of country contexts. The second part of the instrument is the descriptive/explanatory representation of a country's functioning technology development and transfer system, which takes the form of a flow system for each country. The flow system model reflects the actual operation of a country's agricultural technology system and highlights the strengths and weaknesses of individual systems. Both quantitative and qualitative data are collected and compared with norms that are being developed by examining the characteristics of successful systems. The four major functional components of the analytical framework are government agricultural policy, technology development, technology transfer, and technology utilization by farmers. This paper breaks down each major component into its constituent functions and tasks and identifies and describes the key indicators. It includes a directory of members of the INTERPAKS research team and a summary of the project's history and administrative structure. (JHZ)

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Analyzing Agricultural Technology
Systems: A Research Report

by

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Research Director

Paper Presented at the Annual
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ANALYZING AGRICULTURAL TECHNOLOGY SYSTEMS: A RESEARCH REPORT*

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Introduction

This report has been prepared to describe the analytical framework being developed by INTERPAKS to examine and assess agricultural technology systems. This framework is the direct result of work undertaken through a Cooperative Agreement between the U.S. Agency for International Development (USAID) and the International Program for Agricultural Knowledge Systems (INTERPAKS) at the University of Illinois at Urbana-Champaign. This report serves to summarize progress to date and to suggest possible next steps to move in the development of the analytical framework from the research and development (R&D) stage to widespread application.

The Cooperative Agreement

In February, 1984, USAID and INTERPAKS signed a five-year Cooperative Agreement entitled "Technology Development, Transfer and Feedback Systems in Agriculture". The original objectives of the Cooperative Agreement were threefold: (1) to develop a true-to-life model of technology development, transfer, and utilization; (2) to base its creation and progressive refinement on a series of comparative case studies of existing national technology systems; and (3) finally, to extract from the process a set of concepts and tools for practical use in diagnostically assessing systems or parts of systems, with a view toward improved agricultural development.

Considerable progress has been made toward all three objectives, but the process is on-going, requiring further incremental fine-tuning of the evolving framework and tools. Critical inputs into this evolution have been extensive searches of the existing literature, the service of consultants, and the insights and experience of the original research team and subsequent multidisciplinary teams assembled for the case studies. Each successive step of the project has been reviewed and critiqued by an external Project Advisory Committee and the USAID project management team. From all of these inputs, a synthesis is emerging for the application of the analytical framework to assess existing national or provincial technology systems, including their individual functioning parts and relationships. It is this emerging synthesis that is reported on here.

The Analytical Framework

From the outset of the Cooperative Agreement, the INTERPAKS Research Team, the Project Advisory Committee (PAC) and the USAID Project Management Team agreed the project could better be served by something less than (or different from) the pretention of a sharply specified, quantitative systems model, which could not be made sufficiently reliable from the current state of knowledge. The decision was made to develop a different type of systems model, an inductive model, that would allow the user to discover knowledge for himself or herself, and one that unfolds incrementally with progressive refinement based on experience. For purposes of clarity and understanding, the PAC recommended that INTERPAKS refer to this model as an analytical framework, rather than as a formal "systems" model.

The resulting INTERPAKS instrument should be regarded as a descriptive analytical framework which has two parts. The first is a methodology, consisting of a set of indicators, which is a descriptive device that serves to organize data collection and to order data for comparison between countries. By its very nature as an inductive methodology, it requires and allows for adaptations to the realities of country contexts. The indicators, then, are methodological tools that aid the analyst in making a general appraisal of the system and its functional components.

The second part of the instrument is the descriptive/explanatory representation of a country's functioning technology development and transfer system, which takes the form of a flow system for each country. The flow system model is an asbtraction which reflects the actual operation of a country's agricultural technology system, rather than the formal organizational structure represented by government or private sector organigrams. This model portrays the realities of each country and in so doing highlights the strengths and weaknesses of individual systems.

Both quantitative and qualitative data are collected and compared with norms that are being developed by the INTERPAKS research team and by others, such as the International Service for National Agricultural Research (ISNAR). These norms are being developed by examining the characteristics of "successful" systems; systems that have positively impacted agricultural productivity in their respective countries. In carrying out this comparative analysis, these guidelines or norms are being developed to

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**The analytical framework described in this paper is the product of a team effort, initially specified by the original INTERPAKS research team and subsequently revised based on the findings of the case study teams and others. In writing this report, the author received many helpful comments and suggestions from members of the INTERPAKS research team, including J. B. Claar, F. M. Fliegel, E. L. Johnson, W. E. Peterson, A. J. Sofranko, E. R. Swanson, and J. L. Woods.

allow for diagnosis and the identification of potential constraints that limit the effective performance of national technology systems. This analysis, in turn, suggests where interventions should be made on behalf of improvement. Through a comparative in-depth analysis of the four case studies already carried out, as well as through other experiences, both guidelines and lessons emerge to suggest possible options that other countries can consider in making interventions to solve specific problems or reduce constraints.

Indicators

One central dimension of the analytical framework is a series of key indicators that are associated with the primary functions of a technology system. Husen and Postlethwaite point out that an indicator is an objective measure "estimating the level of a single characteristic of a population" and that it possesses generality, i.e., that it can summarize "a large amount of data in a succinct way so as to form a general, overall comment" (pp. 2433-2434). Within the context of the Cooperative Agreement, the INTERPAKS research team defined an indicator as an instrument to summarize both quantitative and qualitative data about the level of resources or inputs, types of organization and activities, and the outputs that are associated with key functions of a technology system.

In the analytical framework, the key indicator in evaluating the overall performance of the national technology system would be its impact on agricultural productivity. The criterion used by INTERPAKS, in judging a national agricultural system as being "successful", was at least a three to four percent annual increase in agricultural gross domestic product (AGDP) in real terms over a 10-year period, where there had been no appreciable change in cultivated area. The assumption is that the utilization of new technology was an important factor for this increase, although other factors, such as changes in economic incentives, also may play an important role in increasing the use of known technology. Two national case studies were selected because they met this minimum criterion and also because they represented vastly different types of technology systems, with respect to geographic location and socio-cultural setting. A third country was selected that made impressive progress until the mid-sixties, when increases in AGDP became much smaller. A fourth case study was selected because the agricultural technology system has had little impact on AGDP in recent years. The purpose of these last two cases was to determine the usefulness of the analytical framework in identifying and prioritizing a range of constraints in the technology system.

Functional and Structural Linkages

The other key dimension of the analytical framework is an analysis of the institutional factors that affect the performance of a national system, with particular emphasis being given to the two-way flow of information and materials through the functional linkages. Initially, the formal structure of the system is mapped to identify the structural arrangement of the system and the enabling linkages. Second, and most critical to identifying institutional constraints to the technology system, is a tracking analysis or flow chart that maps the reality of the functional linkages that integrate the system. The "flow" analysis clearly shows how technological components such as new genetic and chemical materials, as well as cultural practices, enter or are developed by the national system and how this technology flows through the system, including time lags, key decision points and feedback loops, to eventual utilization or rejection by farmers.

Case Study Approach

As indicated above, the effort to refine and test this analytical framework has been carried out through a series of national case studies. A case study is a formal analysis of a national technology system using pertinent descriptive information, indicator data and an analysis of enabling and functional linkages. In the final section of this report, there is a brief discussion of how "expert systems" software could transform the analytical framework and indicators into a more streamlined diagnostic tool to allow national planning units, donor agencies and others to use the tool for more rapid analysis and reporting of the findings, as well as for longer term monitoring of a national system.

THE AGRICULTURAL TECHNOLOGY SYSTEM

The analytical framework developed by the INTERPAKS research team is based upon primary functions and tasks as well as functional linkages. This primary emphasis upon a functional rather than a structural analysis is done so that the framework can be used to analyze technology systems in any type of political economy. Figure 1 presents two types of functions: those internal to the technology system and those external factors that impact the technology system. The four major functional components of the analytical framework, as defined by the INTERPAKS framework, are as follows:

(1) Policy, which includes those external factors that directly impact the technology system, including the utilization of technology by farmers;

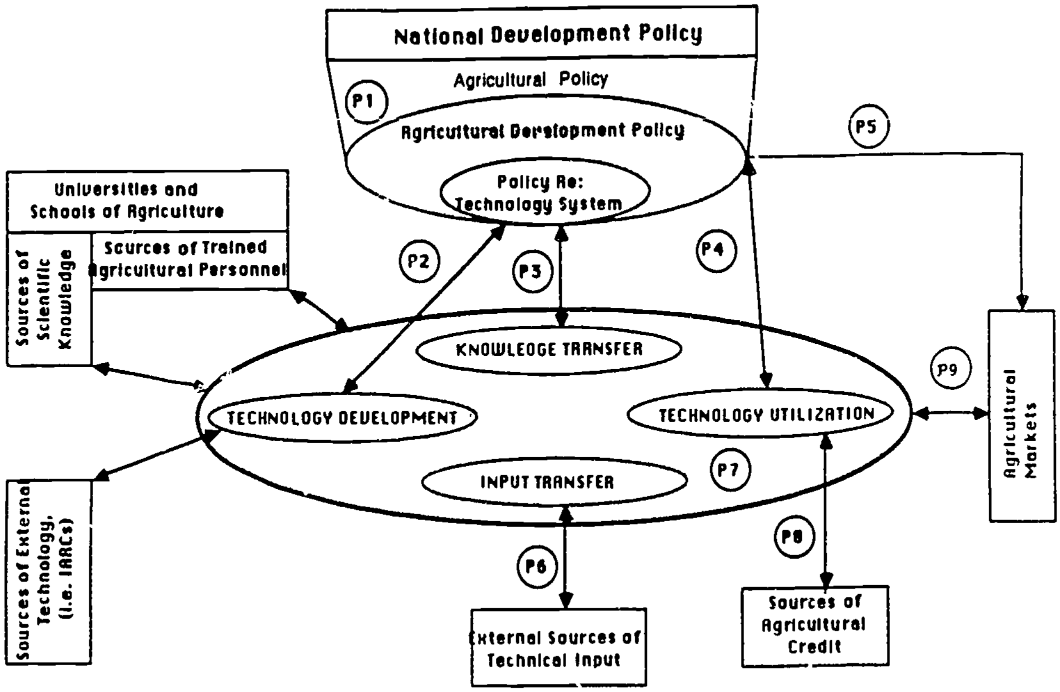
(2) technology development, which includes that part of the agricultural research system that is devoted to applied and adaptive research;

(3) technology transfer, which is broken down into the sub-functions of knowledge transfer and input transfer, and,

(4) technology utilization by farmers, with an emphasis on small holders.

The main internal functions and tasks of the technology system are presented in Figure 2. Knowledge transfer and input transfer can be handled separately, as is the case in many countries, or they can be integrated as is the case of commodity production systems. Integrated or separated, it is assumed that both sub-functions are essential to a technology system. In the subsequent sections, each major system component will be broken down into its constituent functions and tasks, with key indicators identified and described briefly.

FIGURE 1. FUNCTIONAL MODEL OF NATIONAL AGRICULTURAL TECHNOLOGY SYSTEM SHOWING INTERNAL COMPONENTS AND EXTERNAL FACTORS



POLICY INDICATORS

Positive and stable government policy toward the agricultural sector in general, and toward the technology system in particular is of critical importance if a country is to achieve increasing agricultural productivity on a continuing basis. Key indicators have been selected to specify government policy and its impact on either the technology system itself or on the ability of farmers to utilize new technology. Each policy indicator is described briefly.

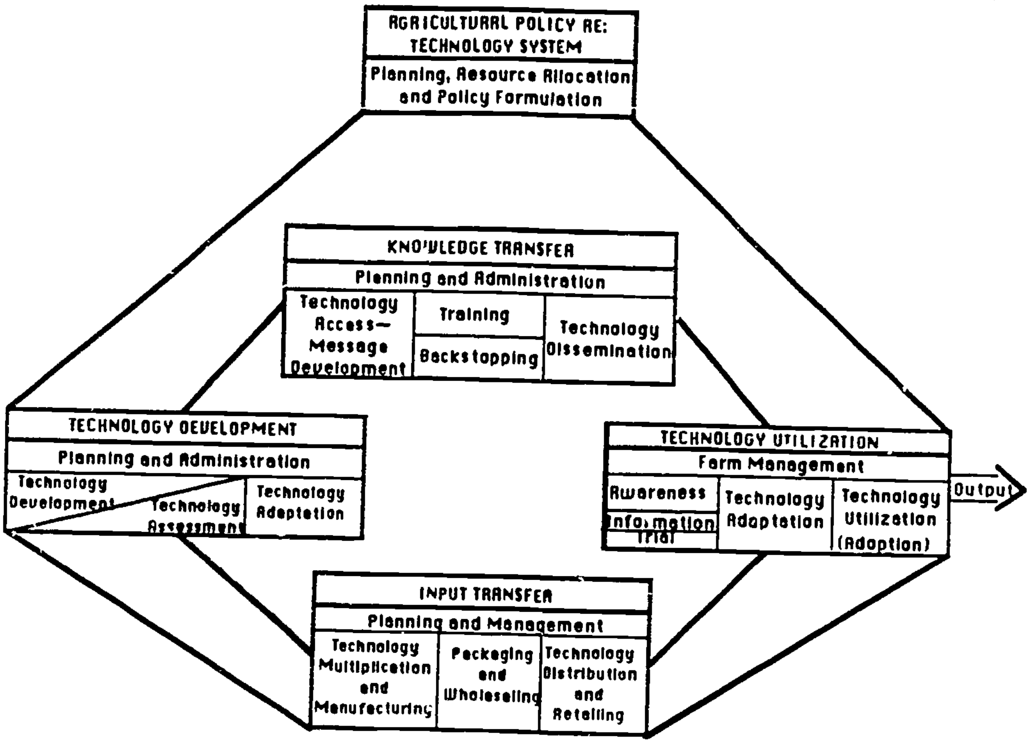
P1. Government's Financial Commitment to Agriculture
This indicator measures the proportion of recurrent expenditures that government devotes to agriculture and agricultural development. An examination of resources allocated to agriculture, as compared to other areas of national concern, such as education, health, defense, energy, etc., enables an observer to determine how agriculture is viewed within the context of national goals and priorities. Furthermore, the proportion of resources allocated to agriculture over time is a reasonable indicator of current trends about the relative importance of agriculture and its development in the overall development strategy of the country.

P2. Agricultural Research Investment
Agricultural research must be viewed as a long term national investment that will directly impact agricultural productivity. This indicator measures both public and private recurrent expenditures on agricultural research over time and relates this investment directly to agricultural gross domestic product (AGDP). A useful rule of thumb is that a nation should invest about 1% of AGDP in agricultural research annually; smaller nations will probably need to invest somewhat more, larger nations somewhat less. For example, in Africa as a whole, it is estimated that only about 0.15-0.20% of AGDP is invested in agricultural research, or about one-fifth of the suggested amount. Some countries actually expend only about 0.03-0.05% of AGDP on agricultural research, which suggests insufficient capacity even to borrow and adapt appropriate technology to increase agricultural productivity.

P3. Knowledge Transfer Investment
Public sector investment in agricultural extension is an important measure of government commitment to knowledge transfer. As is the case with agricultural research, to compute this indicator recurrent extension expenditures are related to AGDP. In the case of integrated commodity or full-scale integrated agricultural or rural development programs, it is difficult to separate out government investment in knowledge transfer. In these cases, the fraction of total person years allocated to knowledge transfer is estimated and the recurrent expenditure pro-rated accordingly. Evenson (1986) estimates that industrially developed countries spend about 0.6-0.8% of AGDP on extension, and these investments are highly productive. However, the farm population in these industrial countries may average only about 5% of total population, as contrasted with 75-85% in some very poor countries. Therefore, widespread knowledge transfer in developing countries will likely require a higher level of investment.

In addition, the *relative* investment in agricultural research and extension should be compared. For example, Evenson (1986) found that industrialized countries spend more than twice as much on research as on extension.

FIGURE 2. MODEL OF AN AGRICULTURAL TECHNOLOGY SYSTEM SHOWING PRIMARY FUNCTIONS AND TASKS



Again, the size of farm population in developing countries will influence the relative allocation of resources to research and extension. Therefore, a well-balanced and sequenced investment pattern, reflective of both the research and extension needs of the agricultural sector, is considered a necessary prerequisite to building an effective technology system.

P4. Farmer Participation In Policy Formulation

Increased farmer participation in the technology system as well as direct farmer involvement in government policy formulation is considered important, both in maintaining the flow of resources to the technology system (Evenson, 1986), as well as in influencing the priorities and programs of the technology system. The presence of farm organizations (commodity specific or general farmer organizations), the level of participation (percentage of farmers holding membership), the method by which leaders are selected (appointed by government or elected by the farm membership) and the levels of organization (local, district, province and/or national) are all important in measuring farmer participation in policy formulation.

P5. Commodity Price Policy

Government price policy sends important signals to farmers which directly influence their ability and motivation to utilize new technology. Farmers are unlikely to adopt new technology unless there are clear incentives, such as increased profitability. If a government pursues a "cheap food" policy to maintain the political support of urban consumers, it is unlikely that farmers can afford to adopt new technology, unless purchased inputs are highly subsidized. Government marketing boards for export crops are sometimes used to extract the surplus from rural producers. Therefore, the indicator used to measure government price policy attempts to compare the farm gate prices for the major staple food crop, the major protein crop and the major cash/export crop (grown by small holders), with either regional and/or world market prices over time to determine the presence or absence of price incentives that would encourage farmers to assume the risk associated with adopting a new technology.

P6. Supply of Purchased Inputs

Technological change in agriculture assumes the increased use of purchased inputs. If a country must import fertilizer, agricultural chemicals and other agricultural inputs, it must be willing to commit scarce foreign exchange to the objective of increasing agricultural productivity. Larger nations may decide to commit capital development funds to build sufficient fertilizer and other types of input manufacturing capacity to meet farmer demand for these inputs. This indicator specifies the amount of fertilizer imported or manufactured in the country and used by farmers over the most recent ten year period. The indicator itself is based on kilograms used/hectare of cultivated land. The percentage of farmers actually using fertilizer is also specified to determine relative accessibility.

P7. Crop Price-Fertilizer Ratio

Input subsidies, price controls and other government interventions into the marketplace can be viewed as signals sent to farmers that, in turn, affect the utilization of technology. The indicator used to determine if it is relatively profitable for a farmer to use fertilizer is the relative cost of 100kgs of nitrogen (N) over the farm gate price of 100kgs of crops. Inter-country comparisons are being made to determine whether specific guidelines emerge out of these cost-price relationships and the increased utilization of fertilizer.

P8. Availability and Use of Agricultural Credit
The availability and use of production credit is particularly important in poor nations if farmers are to have access to improved technology in the form of purchased inputs (improved seeds, fertilizer, chemicals and other inputs). Medium term credit may also be important for farmers to gain access to improved livestock, farm machinery and/or for land development. For this indicator, primary attention is given to the percentage of farmers using production credit and the average size of loan per farmer. These data are compared over the most recent ten-year period to determine trends in availability and use.

P9. Availability and Efficiency of Farm Markets
Farmers will increase their productivity if there are incentives to do so and if there is a reliable market where they can sell their surplus above household consumption. Farm marketing might be conducted by private traders or by a government parastatal, but the external factor measured by this indicator is the distance farmers have to take their produce and the length of time until payment. Farmers might be expected to transport their surplus at least 5 miles or 8 kilometers, but beyond this distance, they might tend increasingly to rely on middlemen, which in turn could increase marketing costs and reduce net income. Therefore, the first part of this indicator is percentage of farmers who live within 5 miles or 8km of a market for primary farm products.

The second dimension of this indicator is the efficiency of farm markets. Efficiency is measured by the normal time required for the farmer to be paid for his or her crop. For example, government buying stations sometimes are conveniently located, but may take 6 months or longer before farmers are paid for their produce. Therefore, under this indicator, a market is considered very efficient if the farmer is paid immediately or within one week, efficient if paid before the beginning of the next growing season (so the farmer has cash available to purchase new inputs), and inefficient if a longer period is typical.

TECHNOLOGY DEVELOPMENT

Agricultural research represents a continuum from basic scientific research and the frontiers of new knowledge on one end, through disciplinary research concerned with knowledge generation in the agricultural sciences, to more applied research programs that focus specifically on the direct application of knowledge and methods to solve particular production problems. The final step in the agricultural research continuum is adaptive research, where new technology is tailored to specific agro-ecological conditions and where socio-economic criteria are sometimes applied in formulating recommendations for farmers.

The analytical framework is primarily concerned with the applied-adaptive research functions, or those research efforts that are directed specifically at the process of developing, assessing and adapting technology to the needs of farmers. The following indicators, therefore, measure specific factors that affect the performance of the agriculture research sub-system concerned with technology development.

Resources
The research system has four main types of resources: (1) financial, (2) human, (3) land, facilities and equipment and (4) scientific and technological knowledge and materials. As indicated earlier, it is generally agreed that the recurrent (annual) financial resources committed to agricultural research "should" be in the range of 1% of AGDP. Since this indicator (P2) was measured earlier, it is merely taken as an input in this section. Here, primary attention is given to the number, quality and type of human resources available to agricultural research. Before considering this indicator, however, the other two resources will be considered briefly. The availability of adequate experimental land, facilities and equipment is of obvious importance in conducting agricultural research. The adequacy of these facilities, however, depends on many factors, such as the type of research being conducted and the quality of scientific and support personnel. Given the complexity of assessing research facilities and equipment, and the macro-level analysis being pursued here, it was decided that it was unrealistic and unnecessary to propose an indicator for this input.

The other primary input into the research system is its access to scientific knowledge and technological materials and information. Access to scientific knowledge is also a difficult input to assess, because scientific information flows through formal systems and informal networks. In fact, technological information and material primarily flows through informal networks although the IARCs have formalized some of these networks in recent years. In assessing this resource, primary attention is given to technological information and materials that flow through the international system, particularly those organized by the IARCs. This input is discussed below under TD5 - Access to External Technology.

TD1. Human Resources
The human resources available to agricultural research are assessed from three different subsets of information. First, the total number of research officers (B.Sc. degree or above, or equivalent) available is a good general measure of research investment, and it too can be related to AGDP. Although the relative cost/scientist/year varies somewhat between countries and parts of the world, overall research investment can be computed by knowing the number of scientists available. Therefore, indicator TD1a is the number of scientists/US$ million of AGDP. For example, in Africa 0.4 scientists/US$ million of AGDP equals about 1% of AGDP invested in agricultural research.

The quality of the research staff is another important factor affecting the performance of the research system. Since the M.Sc. degree and the Ingenieur Agronome are the first qualifications including formal research training, this educational level is considered the minimum qualification for a research scientist. Furthermore, advanced research training to the doctoral level is generally considered essential for those scientific staff providing research program leadership. Therefore, the proportion of research staff with M.Sc. or Ph.D. degree or equivalent training is an important measure of the quality of scientific staff and is included as indicator TD1b.

The technician-scientist ratio (TD1c) is another important factor that influences the productivity of the scientific staff. Technicians are defined as those support staff with 1 or 2 years of post-secondary technical training. In some countries they may have 3 years of technical training, but only through the secondary school level. The rule of thumb generally used for planning purposes is a 2:1 technician-scientist level, if maximum productivity is to be realized from the scientific staff; however, this ratio will vary by field of research.

TD2. Research Organization and Orientation

Agricultural research can be organized in different ways, including by disciplinary departments, commodity (or problem oriented) research teams or some other form. It is generally agreed that developing nations, with limited research resources, should concentrate these resources on applied/adaptive research. This assumption implies organizing research around multidisciplinary commodity or problem-oriented research teams, with adequate adaptive research capacity to modify production recommendations for each major agro-ecological zone.

Smaller countries may decide to orient or limit their research programs to merely screening/testing externally developed technology from the international network and then adapting it to local conditions. Later, they may extend the work of commodity research teams "upstream" to actually develop new technological components (e.g. new varieties), while continuing to assess and adapt externally developed technology to the needs of their farmers. This qualitative indicator, which specifies research organization and orientation, considers the appropriateness of these factors, given the size of country and availability of scarce scientific resources.

TD3. Resource Allocation to Salaries and Programs.

A common problem among some national research systems is an imbalance between resources available for salaries and those available for programs. This problem can arise in several ways. For example, the research service may be required to hire a certain number of university graduates as a matter of government policy; or salaries may increase more rapidly than the overall research budget. The net result is to have scientists with too few resources available to conduct a productive research program. A rule of thumb for this indicator is that there should be about an equal balance between resources for salaries and those for programs. It appears that when the program budget falls below 40% of the overall recurrent research budget, researchers will become increasingly constrained and their productivity reduced.

TD4. Resource Allocation to Commodity Research

Colonial governments usually maintained effective research systems to increase the productivity and production of export crops. Seldom did they invest much in food crops research, particularly for subsistence crops. Some countries gained independence two or three decades ago, but the pattern of research investment may have changed very little. Broad-based agricultural development implies that the productivity of subsistence farmers and the food crops they grow must increase substantially. In doing so, they can be expected to first produce a surplus above home consumption for sale to urban consumers and, subsequently, they will likely begin to diversify, including the production of high value food crops, cash crops and livestock. To allow this process to occur, adequate resources must be invested in food crops research to increase their productivity. This indicator examines the proportion of research resources (either financial, human or both) invested in each commodity research program (i.e. especially the important food crops) in relation to the economic contribution of each commodity to the AGDP. A 1:1 investment ratio is not necessarily assumed to be optimal; however, a major divergence from this ratio would suggest a possible misallocation of resources and the need to rationalize it.

TD5. Access to Externally Developed Technology

A primary input into the research system is externally developed scientific knowledge and technology. Here the primary concern is assessing access to the international network of technical materials (especially improved genetic material), information and training. For the major food crops, this contact will be primarily with the IARCs and their networks, but other networks for some cash/export crops should also be considered. The primary objective of maintaining regular access to this international system is to screen new technology and, where it is superior to locally available technology, to adapt it to local conditions and then release it to farmers. This composite indicator involves three factors (regular receipt of genetic materials, consultation and training) across the three primary commodities (main food staple, protein and cash crop) grown by small farmers.

TD6. Research Outputs

The outputs of an agricultural research system can range from scientific papers published in refereed journals, to the output of technical materials (e.g. new varieties) and recommendations that are found in technical booklets/circulars for extension workers and/or for farmers. In addition, researchers may teach in training courses and workshops or conduct field days for extension personnel and farmers.

These research outputs are summarized by major category for all research workers assigned to the three primary commodity research programs and then averaged to determine the average output/scientist for the most recent year. This indicator gives an indication of both the magnitude and types of research outputs coming from representative programs in the research system.

TD7. Access to Feedback

If research personnel are to stay focused on important farmer problems, they need to have regular feedback from farmers regarding newly released technology; therefore, they must have regular contact with farmers and other intermediaries who perform the technology transfer function. This composite indicator provides an aggregate measure of the level of formal and informal contact between research teams, for the three primary commodities included in each case study, and farmers, extension personnel and other transfer personnel (input suppliers, credit supervisors, etc.).

TECHNOLOGY TRANSFER

Technology transfer can be broken down into two subsystems: knowledge and input transfer. In some national systems or for certain commodities, these two technology transfer functions are integrated. In other cases, these functions are separate. In the analytical framework, indicators are used to measure the key knowledge transfer functions, while the flow analysis gives more attention to assessing the input transfer function.

Knowledge Transfer

As was the case with research, adequate resources must be available if technical knowledge and management skills associated with new technology are to be imparted to farmers. Therefore, knowledge transfer is viewed as an essential human capital investment that must be made if widespread technology transfer is to occur. One relevant measure is the annual allocation of financial resources for the knowledge transfer function. This indicator (P3) was discussed earlier and is taken as a starting point, with human resources for knowledge transfer to be considered next.

TT1. Personnel Resources for Knowledge Transfer

The number, type and quality of agricultural extension personnel are important factors influencing the effectiveness of the extension system. For example, the density of field level extension personnel determines in large part the extent of farmer contact as well as the transfer strategy pursued. The availability of subject-matter specialists affects the linkage between field agents and sources of technology. This indicator has three dimensions. First is the ratio of field extension workers to farm households. This ratio gives some indication of the extent of coverage. For example, the World Bank recommends an average of 1 field agent to 800 farm households under its T&V system of extension. Second is the relative proportion of technical support staff (subject-matter specialists) to administrative/supervisory staff and to field level personnel. World-wide, there are about 8% for administration and another 8% for technical support, but these proportions vary substantially among counties and region. In Europe and North American, where technological change is more advanced and rapid, the percentage of technical support personnel averages around 18%. Under T&V extension, the recommended proportion of administrative and supervisory personnel may range from 12-15%.

Finally, the quality of extension personnel is generally a function of education, training and experience. Therefore, a general indicator of quality is the average educational level of field personnel, subject-matter specialists (SMS) and supervisory officers.

TT2. Personnel Administration and Supervision

It is important to know what kind of managerial/supervisory environment exists for extension personnel, because performance depends not merely on carrying out duties, but also those other intangibles that affect morale, satisfaction, attitude, confidence, and creativity. All these are affected positively or negatively by salaries, quality of supervision and conditions of assignment that make up this composite indicator. First, extension salaries are compared with those of comparable professional groups. Next, the status and role of incentives and sanctions, both material and non-material, are viewed in relation to performance, tenure and advancement. Finally, the general length and conditions of service in an extension office is assessed because it directly impacts performance.

TT3. Time Allocated to Knowledge Transfer

This indicator estimates the percentage of time field level extension personnel devote to knowledge transfer as compared with the non-educational tasks (census data collection, supervising credit, regulatory tasks, etc.) to which extension personnel are frequently assigned. Proponents of extension's central role in knowledge transfer believe non-education tasks dilute the capacity and undermine the credibility of extension personnel to carry out knowledge transfer. Proponents of integrated approaches believe that multiple assignments for field personnel can increase agent efficiency, even though there may be less time for knowledge transfer. This issue is being investigated during the case studies.

TT4. Resource Allocation between Salaries and Programs

This indicator determines the degree of balance between personnel and program costs, or between merely keeping personnel on the payroll and having something productive for them to do on behalf of farmers. It can also show meaningful trends over time, with implied alerts calling for some remedial action. Few indicators will so clearly signal emerging problems as this one does. It can also show the extent of bureaucratization, with its emphasis on employment, instead of performance.

TT5 and TT6. Access to Technology and Message Development

These indicators give specific attention to the research-extension linkage and which agency(ies) has responsibility for message development. Indicator TT5 is a composite measure of the level and type of contact between researchers and extension subject-matter specialists. These contact points include on-station visits and field days, joint on-farm trials/demonstrations, technical reports received and workshops/training courses given by research. TT5 indicates the relative strength of the linkage.

In some national systems, research merely supplies technical reports to extension, which then has the responsibility to interpret data and translate the findings into an acceptable set of production recommendations. In other cases, research formulates technical recommendations and passes this "message" on to extension for dissemination. TT6 is a qualitative indicator of which agency has responsibility for message development. Ideally, message development is a joint responsibility, where research findings are integrated with farmer feedback through extension, (along with information on input supply and credit availability) to develop a message that is both realistic and responsive to farmer objectives.

TT7. Training of Knowledge Transfer Personnel
This indicator measures the average number of days/year that field level extension personnel receive in-service training. In many national systems, the average level of in-service training runs 3-5 days. However, with the widespread adoption of T&V extension, the amount of in-service training has increased substantially, up to 20-30 days per year, because of the fortnightly training sessions. However, unless there are sufficient numbers of competent technical support personnel available to provide increased levels of training, the quality may be low, as indicated in one case study country. Therefore, a qualitative assessment of in-service training is necessary to complete this composite indicator.

TT8. Technical and Professional Backstopping
Subject-matter specialists (SMS) and agricultural information specialists (AIS) are necessary to provide both the technical and professional backstopping for field personnel. The SMSs provide the essential linkage with research; they conduct in-service training courses and deal with special problems identified by field personnel and farmers.

Agricultural information specialists produce the teaching aids, bulletins, and other extension software, as well as radio broadcasts, to support field agents working directly with farmers. These two backstopping roles are measured by the ratio of SMS and AIS to field personnel. In the case of SMS, a ratio of about 1:5 is typical in Europe and North America, but a 1:50 ratio was found in one case study country. The ratio of AIS world-wide is about 1:60, but was found to be 1:130 in the same case study country, with most resources being devoted to radio broadcasts; very few resources were directed to developing teaching aids and materials for field personnel.

TT9. Mobility and Equipment
Mobility and communication tools are both necessary to reach and teach farmers. Farmer contact is severely limited if the field worker can not reach the farm households in his/her service area. It is further limited if field agents have no communication equipment, teaching aids, demonstration materials and supplies to work with once they reach groups of farmers. In a 1983 report, national directors of extension rated mobility of field staff as the most important constraint they faced. In many countries, the lack of teaching aids and equipment is an equally common problem. This indicator examines both issues. First, the percentage of field personnel not having suitable transport is computed. Then a qualitative assessment of the adequacy of teaching aids and equipment is made, based on what items are generally available at the field level.

TT10. Technology Dissemination and Feedback
Technology dissemination is the process by which useful knowledge is transmitted to potential users. New knowledge or technology moves to farmers through a variety of both formal and informal channels. Also farmers go through a multi-stage process of considering whether to use new technology. These stages are thought to correspond with the three main channels of technology dissemination: mass media (awareness), group meetings (information seeking and evaluation) and individual farmer contact (the trial stage of the adoption process). This indicator measures the number of technology dissemination activities completed/field agent/year in each dissemination category. It is widely believed that an effective system will carry out a *balanced* program of dissemination activities in a *comprehensive* approach to knowledge transfer.

Farmer feedback can occur in many settings and through different channels. Measuring farmer feedback is an imprecise task, because it is difficult to determine whether field personnel actually receive the feedback. The one setting where field agents and SMSs are most likely to hear farmer feedback is during on-farm demonstrations and field days. In this setting, both farmers and extension personnel have the opportunity to see and discuss the results of new technical recommendations. Therefore, the completion of one or more result demonstrations per year by each field staff member is a positive indicator that farmer feedback is being received.

Input Transfer
The production and distribution of purchased inputs (i.e. improved seed, fertilizer, chemicals and other agri-services) is an essential part of the technology transfer system. Some system of seed multiplication and distribution is essential to make improved genetic technology available to farmers. The increased use of fertilizer is generally required to exploit the genetic potential of new varieties. Agricultural chemicals used to control pests are, by and large, developed and manufactured in industrially developed countries and imported into developing nations.

Because of the complexity of the input supply system, which may be organized through a number of private and/or parastatal organizations, it is difficult to get an accurate measure of these input supply functions. Therefore, much of the analysis of the input transfer system is handled through the flow analysis, which is described in the next section. One input transfer indicator that should be computed, if data are available, follows.

TT11. Input Distribution Points
Farmer access to purchased inputs is increased when supply points are relatively accessible. This indicator can be computed in two ways, but the first and preferred way is to determine the percentage of farmers living within five miles or eight kilometers of an input supply point. Since most of this distance will be covered on earthen roads and the primary mode of transport will be on foot, bicycle or animal drawn cart, farmers that live within five miles of an input supply point are considered to have reasonable access to purchased inputs. For example, in the Malawi case study, about 75% of all farmers lived within 8km of a supply depot, suggesting ready access. As the percentage of farmers living more than 8km from an input supply point increases, the relative access to purchased inputs decreases as the relative cost of these inputs increases (due to increased time and transport requirements). An alternative measure would be to compute the average number of farm households served by each input supply point.

TECHNOLOGY UTILIZATION

The utilization of new technology by farmers is the primary justification for establishing an agricultural technology system. Widespread utilization of new technology is the key to increased productivity and profitability. Rural sociologists and others have studied the processes by which farmers learn about, consider, try and eventually adopt or reject a new technology. For this component, it is both impossible and unnecessary to measure each of these individual processes or functions. Therefore, the focus is primarily on whether farmers have reasonable access to technology, the percentage of farmers actually using specific types of technology and, finally, the general effect of improved technology on overall national yields. The starting point for this analysis must be a general overview of the characteristics of (small) farm households. All of these indicators depend on the availability of adequate agricultural census data or some other comparable data base, preferably over two or more time periods within the past decade.

TU1. Characteristics of Farm Households
The resources available to farm households can be instrumental in influencing the utilization of technology. For example, the average size of farm and farm household directly influences the types of technology that might be appropriate. The amount of farm household income affects the amount of savings available for purchasing inputs, such as improved seeds, fertilizer and/or chemicals. Other characteristics, such as adult literacy, directly influence farmer access to and the processing of new agricultural information (see Jamison and Lau, 1982). Also, the level of participation in local farm organizations, such as credit societies, farm clubs and/or cooperatives, suggests the percentage of farmers with a proactive orientation toward new technology. Information on these farm household characteristics is essential to understanding factors influencing the utilization of technology.

TU2. Farmer-Transfer Agent Contact
The technology dissemination indicator (TT9) measured the number of individual, group and mass media activities completed by extension. This access indicator focuses specifically on the percentage of farmers who participate in these different types of transfer activities. Therefore, where data are available, the following are determined: the percentage of farmers that

(1) have any type of one-on-one extension contact,
(2) participate in any type of organized group meetings or field days, and
(3) have direct access to radio broadcasts.

TU3. Farmers Utilizing Improved Technology
This indicator measures the percentage of farmers that are actually utilizing various types of improved technology. This indicator must be computed from agricultural census or some other type of survey data, preferably over two or more points in time. For one or more of the three primary commodities (food staple, protein and/or cash/export crops) included in the analysis, the percentage of farmers using improved seed, fertilizer, and one or more recommended cultural practices is computed to determine the level of utilization, and the trend over time. From this indicator, it may be possible to determine the level and type of farmer participation in the technology system. For example, widespread use of recommended cultural practices and, possibly, improved seeds, but with a low percentage of farmers using purchased inputs, such as fertilizer, may suggest a constraint in the input supply and/or credit system. In some countries, census data can be differentiated by size of farm to determine which groups of farmers are participating more fully in the technology system. This type of analysis brings an equity dimension to the study and reveals which groups of farmers are receiving more benefit from the technology system. These findings suggest whether the technology system is contributing to balanced agricultural development.

TU4. Impact on Agricultural Productivity
One general indicator of change in agricultural productivity is the improvement of crop yields over time. The yields of three primary crops (i.e. the main food staple, protein and cash/export crop grown by small holders) are examined over the most recent ten year period, to determine if crop yields are generally improving. While improvement in crop yield is an imprecise measure of change in productivity, it is a useful indicator, taken with other utilization data, to determine if the technology system is having a positive impact on productivity. In addition, where crop yield data can be differentiated by size of holding, these data also give an equity dimension to the analysis to again determine which groups of farmers are benefiting from the utilization of improved technology.

LINKAGE OR FLOW ANALYSIS

An underlying hypothesis of this research was that one important reason why national technology systems sometimes fail to function effectively is dependence on functional linkages which, while intended to integrate the system, actually are either weak or non-existent. Therefore, a flow system model is constructed for each country which assists in identifying linkage weaknesses in the national system.

Flow analysis is a systematic mapping of the functional linkages of the technology system by which new agricultural technology actually reaches farmers. In addition, it traces new technology, or new technological components, from the time they are developed and/or enter the system, until they reach farmers. This analysis depicts the functional arrangement of different institutions in the system, including key decision points and time lags.

New agricultural technology is generally a bundle or package of different technological components, such as improved varieties, fertilizer and/or agricultural chemicals, plus the technical knowledge and management skills needed for their effective and efficient use. Therefore, there are generally multiple paths by which new technology reaches farmers. To a greater or lesser degree, these multiple paths of the technology system are unique to each commodity.

However, given the macro-level focus of the analytical framework, a more generalized type of flow analysis is actually employed.

The three main types of technological or knowledge components that are actually mapped and tracked through the system are as follows:

(1) genetic technology, such as the new crop varieties, hybrids or, possibly, livestock breeds;

(2) agricultural chemicals, such as new pesticides used to control weeds, insects or diseases; and

(3) the new cultural or management practices, such as plant population and fertilizer usage, that are organized into a set of agronomic recommendations adapted to major agro-ecological zones and reflective of the socio-economic conditions under which (small scale) farmers operate. Figure 3 is taken from the Malawi case study and shows how new genetic technology for food crops flows through the national system. As shown in this example, it generally takes from 10-20 years for new genetic technology to be developed, transferred and utilized by farmers. By borrowing new technology from neighboring countries or the international system, however, this time lag can be reduced substantially. By actually tracking the flow of genetic technology for each of the three primary commodities grown by (small scale) farmers, it is possible to identify institutional constraints that may be slowing or blocking the flow of new genetic material to farmers.

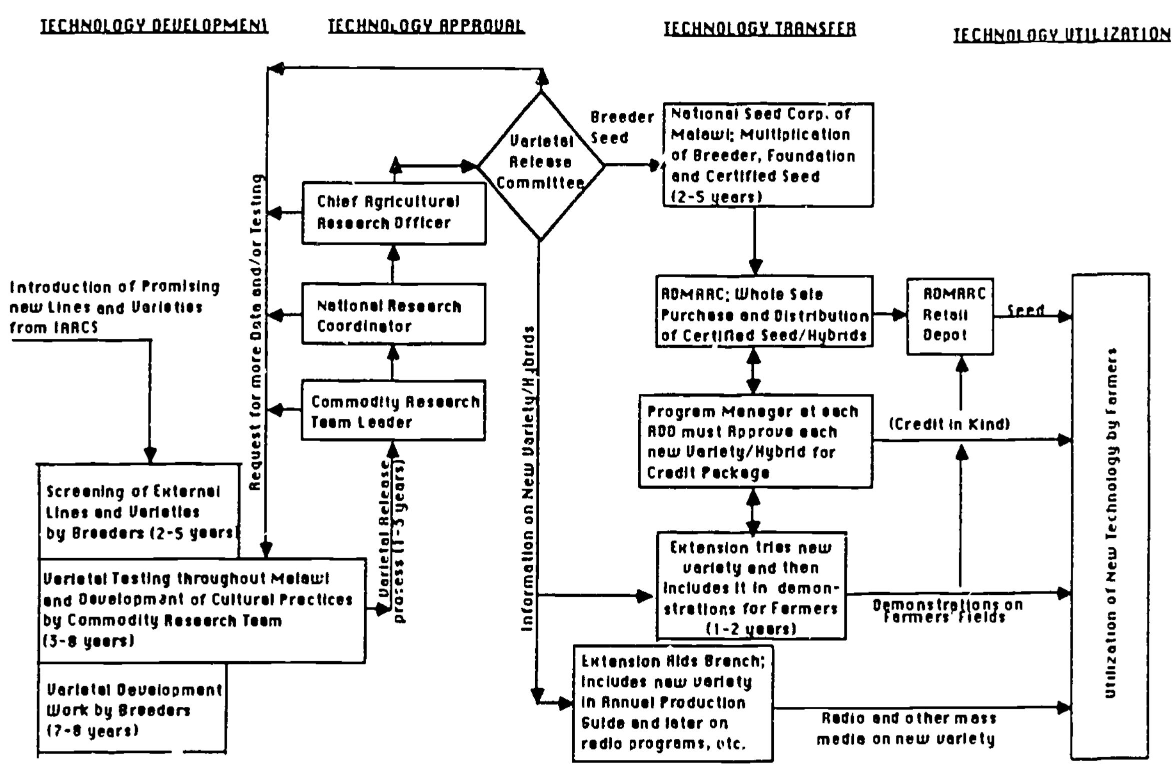
The same type of mapping analysis is also done for chemical technology and the accompanying cultural/management practices. In each case, specific types of technology for each of the three primary commodities are tracked from the research system to the farmer. It is this combination of mapping the functional linkages of the system (how the system is supposed to function) and systematically tracking technology "downstream" (how the system actually functions) that clearly identifies the institutional constraints.

From Analysis to Diagnosis

From the outset of this project, the objective was to produce a diagnostic tool that national policy makers and donors could use to assess constraints in agricultural technology systems. The first step was to define the system and then to develop a comprehensive approach and set of tools that could be used to assess or evaluate the system. From such an assessment, new investments and/or policy level interventions could be made strategically to improve the performance of the overall system.

The emerging analytical framework is responsive to this objective. By focusing on key functions and linkages, the tool can be widely used to assess performance, regardless of the structure or source of support for the technology system. The indicators provide an objective measure of key inputs, functions and outputs of the primary components. They also measure the impact of key external factors that affect system performance, including the utilization of technology by farmers. The flow analysis provides a dynamic perspective as it elaborates and evaluates the functional linkages that facilitate or restrict the flow of new technology to farmers. It is the combination of both indicator data and flow analysis that allows for both a comprehensive assessment of performance and a diagnosis of constraints.

FIGURE 3. FLOW OF NEW GENETIC TECHNOLOGY TO FARMERS IN MALAWI



Possible Next Steps

Recent advancements in the development of expert systems software to operate on micro-computers would lend itself very well to the further development, dissemination and more widespread use of the analytical framework as a diagnostic tool. Expert systems are readily able to handle both quantitative and qualitative data, in a decision framework, to provide rapid analysis and assessment of complex problems, such as assessing a national technology system. A decision framework could be developed to reflect both the theoretical and empirical findings that have been synthesized to date through the analytical framework, plus the reflective experience of the INTERPAKS research and case study teams in using this analytical tool.

Given the complexity of the analytical task and the difficulty of applying these analytical/diagnostic tools solely from an operations manual, it would be useful to have an alternative back-up system, rather than reliance on direct collaboration with INTERPAKS. An expert systems program would give that alternative, and this expertise could be built right into the computerized analytical/diagnostic framework, making it readily available to policy makers, without direct INTERPAKS help. Furthermore, once developed and installed, a planning/policy unit in a Ministry of Agriculture could then use such a system on a long term basis to monitor the impact of new resources and/or policy interventions to improve the performance of the national technology system.

Additional Applications

Although the analytical framework was developed as a macro-level, system-wide diagnostic tool, it can be readily applied to a single commodity technology system. Over the next few months, INTERPAKS and the International Potato Center (CIP) will work together under a small research grant from USAID to apply this analytical tool to diagnose the constraints in one or more national potato technology systems.

International agricultural research centers (IARCs) and other research institutions are under increasing pressure to demonstrate positive impacts of new technology on crop productivity. IARCs collaborate directly with national commodity research programs and both these research groups have a vested interest in moving new technology downstream to farmers. This new activity will primarily utilize the flow analysis and selected indicators that will be specifically tailored and applied to potato technology systems.

For More Information

Inquires about the analytical framework, case studies and research outputs should be directed to:

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The INTERPAKS Team

The University of Illinois' contribution to the Cooperative Agreement has been the research time of senior faculty to develop the analytical framework and subsequently to test, refine and transform the framework into a diagnostic tool through a series of national case studies. Members of the INTERPAKS team reflect the multidisciplinary nature of the problem and approach used to develop the analytical framework. Members of original research team, as well as other faculty and staff that have served on case study teams and in other capacities, are listed below including their field of study and project role:

Burton E. Swanson, Development Studies, International Agricultural Education and Research Director of INTERPAKS, has served as overall director of the Cooperative Agreement, giving leadership to the Technology Development component of the analytical framework and he has been Team Leader for three of the four case studies (Malawi, Jamaica, and Mexico).

John B. Claar, Agricultural Economics, Extension Administration and first INTERPAKS Director, has served as Associate Director of the Cooperative Agreement and has assumed leadership for the technology transfer component and served on the Malawi case study team.

Frederick Fliegel, Rural Sociology, worked on the Technology Utilization component and served on the Jamaica and Taiwan case studies.

Sam H. Johnson, III, Agricultural Economics, worked on the Policy component until he took a leave of absence from the University.

Ear. ..ellogg, Agricultural Economics, worked on the Policy component and the Malawi case study.

Andrew J. Sofranko, Rural Sociology, worked on the Technology Utilization component and the Malawi case study.

Jane Johnson, INTERPAKS Librarian, assisted with the literature review and compiled the first Annotated Bibliography.

Other faculty members, assistants and consultants who have contributed directly to the Cooperative Agreement include:

John Becker, Agricultural Economics and International Agriculture, served on the Jamaica case study.

Robert Bentz, Associate Director of the Cooperative Extensio' ~ ..vice, served on the Jamaica case study.

Mel Chu, Botanist, served on the Taiwan case study.

Kathleen Cloud, Education/Agricultural Economics, served as Research Associate on the Cooperative Agreement, giving attention to the policy component and serving on the Malawi case study team.

Eldon Johnson, Political Science and Senior INTERPAKS Advisor, served as Team Leader for Taiwan case study.

Clarence J. Kaiser, Agronomy and former Director, Dixon Springs Agricultural Research and Extension Center served on the Malawi case study.

Warren Peterson, Anthropology and Extension Education, serves as Research Assistant on the Cooperative Agreement and served on the Mexico case study.

Carolyn Sands, Planning/Agricultural Education, serves as Research Assistant on the Cooperative Agreement where she is documenting the theoretical foundation for the analytical framework and indicators, preparing the operations manual for the framework and she also served on the Jamaica case study team.

Leila Sfeir, INTERPAKS Librarian, compiled the second Annotated Bibliography.

Earl Swanson, Agricultural Economics, assisted on the policy indicators and served on the Mexico case study.

John van Es, Rural Sociology, served on the Mexico case study.

Karin Wisiol, Systems Analyst and project consultant, explored the extent to which systems analysis could be utilized in the analytical framework and, subsequently, she explored the possibility of using "expert systems" to transform the analytical framework into a diagnostic tool.

John Woods, Agricultural Communications and INTERPAKS Director, served on the Taiwan case study and is the Applied Studies Leader.

Lori Snipes, INTERPAKS Secretary, expertly and patiently typed the many drafts of the analytical framework, indicators and case studies.

The Project Advisory Committee

An external Project Advisory Committee was formed to serve as an expert advisory body for the INTERPAKS/USAID Cooperative Agreement. The Project Advisory Committee reviewed and critiqued the analytical framework, indicators and case studies as they are developed. On the basis of these formal reviews, they made recommendations to the Research Team and USAID as appropriate. Members of the external Project Advisory Committee and their respective institutions are as follows:

Dr. Lowell Hardin, Purdue University (Chair)
Dr. Glenn Johnson, Michigan State University
Dr. Bryant Kearl, University of Wisconsin (Rapporteur)
Dr. Vernon Ruttan, University of Minnesota
Dr. Ernest Smerdon, University of Texas at Austin

The USAID Project Management Team

USAID appointed a project manager and a project management team to work with INTERPAKS in implementing the cooperative agreement. The project manager and the composition of the management team has changed during the first three years of the project. During the first six months of the project, Marshall Godwin (S&T/Agr.) served as Project Manager, assisted by Douglas Caton (PPC/RD and later S&T/RD), Donald Anderson (S&T/RD) and Phillip Church (S&T/Agr.). Dr. Caton was the originator of the project idea from the USAID side and he traveled to Illinois during the first year to work with the INTERPAKS research team in formulating the first approximation of the analytical framework.

Dr. Wendell Morse (S&T/Agr) assumed the responsibilities of Project Manager later in the first year and provided leadership for USAID while the analytical framework was being formulated and refined into its present form; he played an instrumental role in assisting the research team to field test and refine the analytical framework through the first two case studies. Subsequent Project Managers included *Ron Curtis* (S&T/Agr), *Kenneth Swanberg* (S&T/RD) and *H.S. Plunkett* (S&T/RD). Drs. Plunkett and Roberto Castro (S&T/Agr) currently serve as co-project managers.