Considerations for the Development of National Agricultural Research Capacities in Support of Agricultural Development

International Service for National Agricultural Research

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

Of the thirteen centers in the CGIAR network, ISNAR is the only one which focuses primarily on national agricultural research issues. It provides advice to government, upon request, on organization, planning, manpower development, staff requirements, financial and infrastructure requirements, and related matters, thus complementing the activities of other assistance agencies. Additionally, ISNAR has an active training and communications program which cooperates with national agricultural research programs in developing countries.

ISNAR also plays an active role in assisting these national programs to establish links with both the international agricultural research centers and donors.

ISNAR is supported by a number of the members of CGIAR, an informal group of approximately 30 donors; it includes countries, development banks, international organizations, and foundations. In 1984, funding for ISNAR's core program was provided by:

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Philippines
Spain
Sweden
Switzerland
United Kingdom
United States Agency for International Development
World Bank

Citation:

International Service for National Agricultural Research. **Considerations for the Development of National Agricultural Research Capacities in Support of Agricultural Development.** 1984. The Hague, Netherlands.

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October 1984

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I. INTRODUCTION

This paper* highlights the issues and basic relationships that affect the shape and success of national research systems. Emphasis is placed on the identification of specific conditions which experience indicates should be met to ensure effective operation of the research processes. It recognizes that, given the nature and role of research activities, the organization of research systems will vary significantly from country to country, depending on their size, diversity of agro-ecological environments, stage of development, and socioeconomic and politico-administrative characteristics.

Certain aspects that arise out of the scientific nature of agricultural research are common to any R & D activity. The differentiating factors result from the problem-solving orientation of agricultural research and its direct linkage to the technological change process. This latter relationship requires research to be closely integrated with the specific contexts in which research results are to be used, and research organizations to reflect the particular characteristics of the environments in which they operate.

The principal ideas and concepts that ISNAR follows in its work with developing countries in the improvement of national agricultural research capacities required to support agricultural development are synthesized in this paper. It is not an exhaustive discussion of the different aspects and perspectives involved. On the contrary, it represents a stage in an evolving process in which the experiences generated through ISNAR's and other organizations' country-level activities play a central role. In this sense, it reflects ISNAR's experience accumulated during its four years of operation, in which collaboration of different types and depth have been maintained with more than 25 countries, plus observations of others.

The paper has this introduction and four additional sections: the policy environment of agricultural research; the processes that are essential to the operation of the research system; the role of the system's organizational structure; and, a summary of the main concepts put forward in the paper.

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* This paper has been developed out of ISNAR's experience, the experience of others, and a review of recent literature on the subject. It will continue to evolve as ISNAR's experience grows. While Dr. Eduardo Trigo, Senior Research Officer, and Dr. William K. Gamble, Director General, ISNAR, have taken the lead in the development of this paper, it represents a total ISNAR staff involvement.

II. THE POLICY ENVIRONMENT OF NATIONAL AGRICULTURAL RESEARCH

Strong political support and a favorable policy environment are usually identified as necessary conditions for the emergence of strong and effective research systems. In principle, the validity of the relationship is beyond doubt. However, to be of practical value in developing national research capacities, the specific policy dimensions involved and the nature of the needed political support must be elucidated.

As a scientific activity, agricultural research relates to the nation's science policy, to its scientific institutions, and to the global complex of related research activities. A nation's agricultural research also affects, and is affected by, the agricultural policy environment. Agricultural policies affect research priorities and are in turn affected by research capabilities. Furthermore, agricultural policies either facilitate or inhibit the adoption of new technologies that flow from the research system.

Agricultural Research as Scientific Activity

Agricultural research is above all a scientific activity. It is not possible to do research without science. The creativity and scientific quality of the system's resources will determine the effectiveness of the research effort. From the national perspective, and particularly for small developing countries, the central policy decision is over the size and degree of sophistication required to meet the country's research needs.

The size of the research effort is essentially an economic question: what the country can and is willing to invest in agricultural research. It depends upon the political commitment to agricultural research and will be dealt with below. The degree of sophistication of the national agricultural research system is relevant here. How much and what type of research is needed? Does every country need to go into basic research?* What are the alternatives? No clear-cut, definitive answers can be given outside the context of specific country characteristics, but some general comments can be made.

National agricultural research is not an isolated effort. On the contrary, it is an integral part of a world complex of research institutions and activities ranging from the basic and specialist institutions in developed or developing countries, through the regional and zonal networks involving groups of similar countries, to the final testing of new materials and methods in the fields of individual farmers in one particular country. This represents a vast pool of information on which national research can and should draw to avoid wasteful duplication of effort. National activities also contribute to this pool of knowledge and technological information.

Borrowing, however, is rarely a straightforward process, since technologies often are not directly transferable from one country to another. Agricultural technologies can be highly location-specific and sensitive to agroecological, socioeconomic, and even the political environments of the farmers who use them. The problems, risks, and limitations of direct transference of research results are well documented throughout the developing world.

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* Research leading to increases in agricultural production results from the integration of knowledge derived from many sources. The research components can be classified in a variety of ways and various terms have been used. Here, we use the terminology suggested in the Second Review of the Consultative Group on International Agricultural Research (CGIAR):

i) *basic research* – that designed to generate new understanding (e.g., how the partitioning of assimilates is influenced by plant height);
ii) *strategic research* – that designed for the solution of specific research problems (e.g., a technique for detecting dwarfing genes in wheat seedlings);
iii) *applied research* – that designed to create new technology (e.g., breeding new varieties of dwarf wheat that can respond to high levels of nitrogen without lodging);
iv) *adaptive research* – that designed to adjust technology to the specific needs of a particular set of environmental conditions (e.g., incorporating dwarf wheats into farming systems of the rainfed areas of the Pampean Region of Argentina).

There is also much evidence that little borrowing is accomplished without a substantial capacity to do research: to borrow effectively, it is necessary to be able to screen and interpret the possible alternatives, and this requires the capacity to do research. These experiences highlight the importance of and need for a national research infrastructure if a country wants to capture the potential benefits from the pool of already existing knowledge and technological information. They do not imply, however, that all levels of research capability must be present in the country.

Generally, as we move from technology to basic knowledge, location specificity diminished and, consequently, transferability increases. Out of this general observation, and not taking into consideration the case of some types of basic research that can not or will not be conducted outside specific environments, an important rule of thumb can be proposed about the minimum research capacity that should be present in a country.

Given that the ultimate objective of the agricultural research system is the improvement of production conditions in the agricultural sector, the minimum capacity required is the capacity to diagnose and evaluate situations and problems, identify and test alternative solutions, and adapt technologies to local conditions.

Two key issues are related to this approach. First, effective work at this level requires researchers of the highest competence, and not personnel with a first academic degree, as is sometimes assumed. The usual situation is one of isolation, where success is highly, if not absolutely, dependent on the initiative, scientific competence and creativity of the individual researchers involved. Under these conditions, these minimum-level systems may well require a higher average level of skills, training, and experience than the larger more mature systems. Second, there is a need to appropriately recognize the importance of the information linkages through which the system functions and the development of instruments that facilitate interaction between the national system and the sources of information outside the country.

The personnel and resource requirements of a minimum capacity system will depend on the complexity of the agricultural situation the research system has to serve (number of products, agroecological conditions, etc.). But it is crucial to stress the importance, even at the minimum level, of having a critical mass of resources in line with the system's stated objectives. Failure to recognize this requirement or, in other words, the implicit belief that it is possible to do research without scientists, is one of the most common weaknesses of the research systems in developing countries. An indicator of this is that in most of the ISNAR reviews for analysis and planning of national agricultural research systems, serious deficiencies have been identified in the level and quality of the personnel available to the research system.

Agricultural Research as an Agricultural Policy Instrument

We have already pointed out that the ultimate goal of agricultural research is to improve the conditions of agricultural production. Its direct output, however, is knowledge, either incorporated into new production inputs as information about process organization or ways to use specific components. For this knowledge to affect production it must reach farmers, and they must adopt it. The adoption decision is made by farmers, who assess the technological information resulting from research, together with the whole set of other factors that affect the profitability of their enterprises, such as price support, agricultural services, input distribution, subsidies, credit, taxes, and marketing policies, and their own resource base, particularly land and labor.

Various situations highlight the nature and importance of these interactions: for example, the differences in the adoption patterns of new wheat and rice technologies in India up to 1976/77. At this time, 72% of the wheat area was planted to high-yielding varieties, while only 36% of the rice area was under the new

technology. One important reason for this was the price treatment received by the two crops: wheat prices were kept in line with or above the world price, while rice prices were maintained at about half that level due, at least in part, to the apparent overvaluation of the rupee. Another case highlighting the importance of interactions is that of hybrid maize in Kenya, where the high adoption rates are clearly explained by a number of policy changes designed to complement the efforts made at the technological level. Examples of negative effects are unfortunately more common, particularly in regard to food crops and the negative impact of low food price policies.

The interactions between research and economic policy are not only in their nature and level of definition, but also in how they are implemented. Sometimes the non-adoption of given technologies cannot be explained by economic factors alone, but rather because farmers were not confident of the agricultural service system's capacity to deliver key inputs in the amounts and in the time required by the new technologies. An interesting illustration is the apparent reluctance of rice farmers in the Dominican Republic to move into two crops per year production patterns, even though appropriate technology is available. Farmers lacked confidence in the ability of the farm machinery and credit services to deliver their services with the time precision required by the two-crop pattern. The traditional "ratooning" practice seemed more secure to them.

To account for the interactions between agricultural research and the agricultural and economic policy domain, relationships at different levels must be considered. The first is at the research priority-setting level. Here, the relationship is a complex one, given the long-term nature of research and the time gap between initiation of research and the availability of research results. If farmers in their decisions on what innovations or new production methods to adopt take into consideration their effect upon profits or income, then it is crucial for agricultural research to consider the farmers' economic environment when setting priorities and allocating resources to different research options. These two processes take place at two different times. Research priorities have to be set on the basis of policy objectives and goals, and their accuracy will depend on how well-defined and realistic these goals are in terms of the country's long-term interests and resource availability, as well as how capable policy makers are of implementing the necessary policy actions.

Priority-setting is one of the most important weaknesses and difficulties encountered in attempting to develop realistic national research efforts. In many cases, policy objectives are defined too broadly to be a useful guide for research priority-setting. Often, they are unrealistic in relation to available resources; they address problems for which research is a weak policy instrument; or, when well defined, policy implementation bears only a vague resemblance to them. This last aspect points out another crucial type of interaction, which takes place at the implementation level. Here the main concern is with achieving the needed operational coordination between technology and the delivery of the rest of the agricultural services. Frequently, this is a severe problem area that receives very little attention when attempting to improve the performance of agricultural research systems.

Another very important issue is that of the stability of the policies affecting the use of the results of research. Given the long-term nature of research and the gap between the time of investment and results, stable policies which properly reflect long-term characteristics and objectives are essential elements for a successful research effort. With frequently changing policy emphasis, it would be very difficult to develop the required operational interactions between research and the other policy instruments, and there would be a significant loss of the potential benefits of agricultural research.

Political Support for Research Activities

Agricultural research in developing countries is essentially a public sector activity. As such, it is

highly dependent on its ability to attract adequate political support in order to develop and establish an effective claim on present and future resources. Without political support, the long-term development of a national agricultural research system would be very difficult if not impossible, even in those cases where substantial resources from external sources were available.

While the importance of political support is generally recognized, the institutional processes involved are seldom discussed. Here we can only highlight some of the issues that influence the development of support for national research systems.

The importance of agriculture within the country is perhaps the most important determinant of the kind of support that research can expect to receive. The larger the relative economic and social size of agriculture, the more attention it is likely to receive from policy makers and policy-making bodies, and the more politically important agricultural issues will become.

However, in many countries agricultural research has lacked, and still lacks, the necessary support, despite agriculture being the principal sector of the country, in both economic and social terms. This lack of support is also surprising, given the high rates of return that have been reported for investments in agricultural research – usually in the 40-60% per annum range and higher. The level of development and sophistication of the country's institutional system, and the nature of the problems in the agricultural sector, are important in understanding the rationale for political support for research activities.

Agricultural research requires a fair degree of sophistication in the institutional and political systems involved. One reason is the long time lag (and risk) between investment and results; another is the need to design policies geared towards the concept of manipulating science for production and to link science and technology with economic growth. These ideas require the capacity to articulate and implement long-term policies and a high degree of technical participation in the policy-design process. Both aspects have been identified as among the weakest elements of the national agricultural research systems with which ISNAR has collaborated. Long-term policies often do not exist, and, when they do, they are too vague to provide a proper framework for determining the possible contributions of research to development.

Further evidence of the importance of certain minimum levels of institutional development as a prerequisite for support to national agricultural research is that in most of today's developed countries, public research institutions were a late development not taking place until the turn of this century. This fact calls for a reconsideration of the value of the high rates of return on investments in mobilizing strong political support for agricultural research, and suggests the need to consider "political" or "politically adjusted" rather than straight economic rates of return. Because of the long lag between efforts and results, agricultural research investments have a maturation time that usually exceeds the terms in office of decision makers. At the same time, results, when available, are not easily linked to the initial research activities.

Given these circumstances, under weak institutional situations, with no long-term perspectives or capacities to link scientific efforts to development, politicians will assign a low priority to investments in research, no matter how high the expected economic and social returns may be. In the early stages of the development process, this effect is further reinforced by the nature of the alternative uses of the funds that would otherwise go to agricultual research. Then, research is competing with basic social investments such as health and housing or with the development of the country's economic infrastructure, alternatives that usually have higher political priority.

The nature of the problems in the agricultural sector and their relation to the rest of society also affects the political interest in agricultural

research, essentially through their effect on the demand for research. As production is threatened, for whatever reason – pests, wars, etc. – or as the possibilities for horizontal expansion are exhausted, and the demand for food and other contributions from the agricultural sector to overall political stability and economic development increases, the need for more intensive production technologies, and consequently for research, becomes increasingly evident. Technology then becomes an important political issue and will attract the interest and support of the political system.

Examples of this process at work are the creation of some of the early research stations in Latin America, e.g., La Molina in Peru, the American efforts to develop tropical products research in Ecuador and Central America – Interamerican Institute of Agricultural Sciences (IICA) in Turrialba, Costa Rica, today known as Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) – during the early years of World War II, and more recently, the creation of the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) in Brazil. Other cases which may be cited are Japan at the beginning of the century, where food riots led the Japanese to invest in research in their rice supply areas; the early development of the commodity research institutes of colonial times in Asia and Africa; and those of some countries in south and southeast Asia – India, Pakistan, Philippines, Thailand – where rising food prices resulting from the food crises of the 1960's led to significant institutional reforms and increases in research expenditures.

At a different level, the creation of the CGIAR system is also an example of how "crisis" situations attract attention and support for agricultural research. For it to happen, however, there has to be an institutional system capable of translating political goals into technological objectives and scientific problems, and establishing two-way communication channels between agricultural research and its political constituency. There is a "vicious circle": capacity is required to develop support, but support is needed to have capacity. International assistance in general and ISNAR in particular can contribute the most in breaking this vicious circle: the former, by providing the capacity required at the initial stages; the latter, by establishing a dialogue with relevant policy-makers to increase their awareness and understanding of the requirements and potentials of national agricultural research systems.

III. THE BASIC PROCESSES OF AN AGRICULTURAL RESEARCH SYSTEM

The political aspects already discussed will determine the context of the agricultural research system: its overall size, the importance of the research effort, its standing in the politico-administrative ladder, and the breadth of its scientific components. In a way, these elements will determine the amount and type of product that a particular society will expect from its research system. The system's responsibility is to turn out that product in a continuous, cost-effective way. To do so, it must carry out a number of basic processes which are essentially the same, no matter how complex and sophisticated the expected research product is.

For research to be successful, these processes need to generate a self-sustained recursive cycle between products and resources and the continuity of efforts required. Below we focus not so much on the outcomes of each process, but on how they are set in motion and the role each process plays in relation to the overall objective of the system. Seven broad processes can be identified as essential.

1. Directing activities toward the country's priorities, opportunities, and problem areas. The careful choice of priorities and best opportunities is probably the main issue to consider when discussing agricultural research systems capable of supporting a country's agricultural development. In order to do this, two processes of a different but related nature must be considered. The first is identification of the problem areas on which to target the research effort; this is the *planning* side of the process. The second is the definition of the research effort itself; that is, specific topics and the scientific avenues that will be pursued in attempting to reach the established research and development objectives; this is the *program formulation* side of process.

For agricultural research to be effective and efficient, then, it should properly reflect:

a) the potentials of the country's natural resource endowments;
b) agricultural and development policy priorities;
c) charateristics and problems of the production sectors; that is, the farming, trading, and processing communities;
d) scientific opportunities to intervene and improve the production systems.

On the basis of these elements, long-term objectives must be selected and priorities assigned to them. They in turn must be disaggregated into shorter-term quantifiable objectives and goals reflecting the research system's present and projected capacity. This requires the capacity to communicate effectively with policy-makers and with producers, and to process the information that flows from them into priorities at different levels. The planning process comprises the essential element of the linkage between the research system and the country's policy-making level. Operationally, it is an outward-looking, top-down process requiring analytical methodologies for the identification, analysis and evaluation of alternatives, and requiring procedures that facilitate the flow of information and interactions necessary among the different policy and decision-making levels involved in the priority-setting exercise. In designing these procedures, it is essential to recognize the political nature of the final decision about priorities and the need for the information flows to reflect this nature.

Program formulation is a different process. It takes place within the context of a given set of priorities and overall allocation of resources. It is a bottom-up, scientifically informed process oriented toward bringing real-world problems and needs, and available resources, together into a feasible program of work. The list of important research topics that may or need to be undertaken in reference to any situation is almost endless. Of these, however, only a small fraction will be viable, given the quantity and quality – the level of training and areas of expertise – of the system's human resources and the state of the art in the disciplines involved. In this context the system must be able to translate priority problem areas into relevant researchable questions and feasible projects. The basic issues here are research problem identification and

how to select the most appropriate scientific perspective for each problem and frame the specific experiments and studies to produce results that might realistically and usefully be put into use.

In contrast with developed countries, program development is perhaps the area in which the developing world's agricultural research systems are weaker. In the developed countries, farmers usually have a high level of articulation with the research system. They are well informed and are able to identify and express their problems and research needs in a clear and direct way. At the same time, there are a number of mechanisms and incentives that facilitate and promote the research system coming in contact with these problems and developing research perspectives with the appropriate disciplinary breadth. The kind of relations that exist between research, education, and extension, the constant interaction (guidance) between senior and younger scientists, the peer review system, and the competitive resource allocation system can be seen as a "natural" framework for program formulation as defined above. Furthermore, the more effective the functioning of the market as an integrator of technological alternatives, the less emphasis is required on the research system producing "whole" technological alternatives. These are not the conditions prevalent in the majority of the developing countries; so more formal procedures are needed to assure the development of an effective program. One concern should be with having relevant and effective information about the problems and constraints facing the clients of research. These include not only the diverse farming community, but also the other agricultural services – with extension occupying a prominent place in that grouping – and the policy makers. A second requirement is related to the need to assure an interdisciplinary perspective both in the assessment of the situation and in the actual conduct of the research.

2. Mobilizing and effectively utilizing the needed financial resources. Adequate financial resources, in amount and in continuity through time, are a necessary condition for a highly productive research system. How much is adequate is one of the key issues in analyzing a national research system, the problem being that a country's needs for agricultural research are not necesarily consonant with what it can afford. This dilemma probably has no solution other than developing a stable compromise between available or viable funding and needs, but it is one of the most important functions of agricultural research management.

Two functional levels are involved. One is the procurement of resources, the other is the administration of the funds. The first implies selling agricultural research to the proper policy and other decision-making bodies in government and in society at large, establishing a successful claim on present and future resources, and developing efficient mechanisms for funds to flow to the research organization on a continuous basis. The second involves the development and implementation of administrative procedures that insure the optimal utilization of whatever level of funding is available. In setting up these mechanisms, proper consideration must be given to the close interrelationship between funding and financial management and resource allocation, and the monitoring and evaluation process.

3. Developing and maintaining a physical infrastructure that responds to the country's agroecological charateristics and economic potential. Two factors influence the research system's physical facilities. The first is the level of infrastructure and type of equipment needed; the second is the need for physical decentralization that arises from the location-specific nature of agricultural research. Certain types of research must be undertaken under the actual agroecological conditions in which the results will be used. This requirement may imply the need to replicate physical facilities throughout the major regions of the country. The extent of this coverage, however, should be in line with the country's economic ability, not only in terms of the capital investment required for setting them up and the recurrent costs necessary to operate them, but

also, and more importantly, in terms of the human resources available to the research system. Here, the main issue is the need to have a minimum critical mass of researchers at each location. Operationally, the system must have the capacity to recognize the conflict between needs and possibilities, and to be able to establish a set of priorities for allocation of resources that are coherent with the main thrust of the research program.

4. Developing and maintaining a critical mass of well-qualified scientific personnel. People are the most important element of a research system. Even with appropriate physical and financial resources, a research system will only be as effective as the scientific creativity and the organizational and administrative ability of its human resources. These human qualities are needed for identifying problems to be researched, for selecting the research strategy to be followed, and for implementing the research projects themselves; they are functions of both training level and experience. Consequently, the system must develop a cadre of research personnel of appropriate size and disciplinary mix, and must also provide a work environment with enough stability and continuity for the required experience to be developed. Practically, this means having a human resources development plan that reflects the system's needs and potential, and personnel policies that include incentives for achievement, and that creates the conditions of stability and continuity needed for the professionalization of researchers and the development of the required organizational and administrative expertise.

5. Taking advantage of all scientific capabilities available at the national and international levels. National agricultural research is not an isolated effort. It is a component within a worldwide complex of research activities, ranging from the academic and basic research centres, to the testing of the new materials and practices in farmers' fields. This means that in a number of areas national requirements can be served out of this worldwide inventory of specialized knowledge, freeing resources for the development of research relevant to local needs. National research results are also a contribution to the world's pool of knowledge. What is required is the existence of the information and exchange mechanisms that make access to that pool of knowledge possible.

Similar considerations apply nationally. In each country there are usually a number of important capacities, outside the main agricultural research institutions, that can and should be used. Often these capacities reside within universities, where a wide spectrum of expertise and knowledge is usually available, but because of financial or institutional problems they are not involved in research activities. This may also be the situation with the private sector, which can be both a client for and an active partner in the research effort, facilitating an increase in resources and bringing research closer to the end users. To take advantage of these resources requires administrative flexibility, and above all, clear institutional policies that seek and facilitate cooperation.

6. Assuring the flow of information between research and extension workers, farmers, policy-makers, and the public. Effective two-way communication with technology users is one of the keys to a system's success. For research to pay off, the system must generate and effectively deliver technologies that reflect clients' specific circumstances. Feedback on the performance of those technologies under actual production conditions, and on producers' needs, opportunities, and problems is also needed as an input for the planning and program development processes. This requires that research becomes an integral part of the technology transfer system. It can do this by establishing appropriate diagnostic and testing methodologies, by documenting research results in formats that are appropriate for the various audiences they intend to reach, and by developing interactive mechanisms with the technology delivery system, be it the extension service or any other type of organization.

Similar interactive mechanisms are also needed

at the policy and political levels. Some interactions at this end of the spectrum are of a specific, functional nature: research that produces information that is relevant for policy making must be put into appropriate formats and delivered to those in government responsible for the development of agricultural and other policies. In turn, general policy orientations are needed as inputs for planning and program development. Beyond these functional needs, there is the interaction with society's political bodies. Here, the exchange is to enhance the public image of agricultural research and through this to assure the continuous flow of resources needed for the effective operation of the system.

7. Monitoring and evaluating program implementation. Monitoring and evaluation are essential in all processes and organizations. The capacity to measure results against planned realistic objectives and targets, and to introduce program adjustments as implementation proceeds, is a key management function irrespective of the kind of activities the organization is involved in. The uncertain and long-term nature of research, however, imparts great importance to this function. To avoid waste of resources, there must be the capacity to introduce interim adjustments that may be indicated by intermediate results. At the same time, keeping programs in line with national priorities and farmers' problems requires the evaluation of the scientific quality of research as well as of the impact of research results on the production sectors.

Besides being necessary for effective management, monitoring and evaluation are also required for producing relevant information for dissemination at the political level in response to the ever-present issue of the accountability of publicly funded research systems.

IV. THE ROLE OF THE ORGANIZATIONAL STRUCTURE

The above processes are not independent of each other and do not take place in an institutional vacuum. They are performed within a particular organizational structure, which influences the system's effectiveness. It can facilitate or impede the functioning of the system and its ability to turn out the expected product.

In general, by the organizational structure we mean the institutional forms and mechanisms through which human, physical, financial, and information resources are brought together for the operation of the research process. It comprises the durable organizational arrangements through which responsibilities and authority are distributed and the reporting relationships; these reflect the patterns for division of labor and coordination among the different units responsible for research. It also includes the channels for interaction with the system's environment which reflect the system's guidance and input mechanisms. Specifically, organizational structure is the number and types of organizations that perform research, their responsibilities (mandates) and internal characteristics, the patterns they follow in communicating and working with each other, and their governance and resource acquisition mechanisms. Within this overall context, several points are relevant when discussing the role of organizational structures in the development of national agricultural research capacities.

Coherence with country situation and basic characteristics. The organizational structure adopted in each case needs to be coherent with the country's resources and must successfully integrate with social, economic, political, and administrative institutions. In most situations, agricultural research organizations are public institutions, supported by public funds. If they are to be a permanent institutional feature with the continuity required for research to mature and produce results, their size, in economic terms, must be in line with what the country can afford. If it is too large, it will not be able to establish a permanent and stable claim on public resources. This relationship should be taken as valid even where there is an important external funding component and should cover capital as well as recurrent cost requirements. Agricultural research must also interact with and be part of the country's institutional system. For this to be possible, the organizational structure, especially in the linkage components of the system, must reflect the prevailing institutional philosophies and styles.

Unfortunately, there have been many failures in establishing strong and stable systems that can be readily associated with the failure to recognize these basic relationships. The cyclical crisis that has plagued many of the Latin American systems over the past 15 to 20 years is an example of this problem and may be interpreted as an expression of the process by which original ill-fitting institutional formats are successively modified and adjusted to become compatible with other local institutions.

From a similar perspective, the present reorganization of the Spanish research system, which involves breaking the formerly centralized national research institute into several independent autonomous bodies, can also be seen as an effort to put the research system in line with the new federal political structure that Spain is adopting. The U.S. experience with the Land-Grant Universities-USDA model is a very good example of the dynamics of this type of relationship, and of how an organizational format that closely reflects the country's politico-administrative characteristics contributes to the development of an effective research system.

Capability of adapting to change. Another important dimension of organizational structure is its need to evolve and adapt to new situations. Agricultural research is inevitably associated with the long-run and the concept of change. Indeed, the concept of change is what moves society to invest in research. Consequently, the organizational mechanisms must be able to adapt and perform effectively in the new situations that will result from their own success. They must be able to promote creativity and operate with flexible

administrative criteria, routinely revising priorities and incorporating internal organizational (and operational) changes as needed.

The key issue is how to evolve without disrupting the research effort. The most important aspect of this evolution is the need for effective coordination mechanisms and even the redefinition of the mandate of individual research units as the system grows and priorities change.

Need to interact with a broad range of interests. A more specific interaction between organizational structure and the essential processes of the research system occurs with the linkages with relevant social sectors. Earlier, we stressed that research is an integral part of the agricultural policy complex. As such, to be effective it needs a close relationship with all those groups that have specific interests in the technology generation and transfer process – producers and their organizations, agribusiness and the business sector in general, universities, research centers in other areas. These interactions are essential in incorporating the perspectives of these groups into the policy-definition, priority-setting, and program development processes; and also to relate agricultural research with the other research and technology development activities in the country. Through these interactions, it is possible to attract interest and mobilize support to secure the needed flow of funds to agricultural research.

The system's governance mechanism plays an important role in this. There are a number of options which can be grouped into three broad categories, each of which offers a different range of possibilities and benefits. They are:

(a) research is conducted as part of the line activities of one or more ministries;
(b) responsibilities for research are assigned to one or more autonomous organizations, each having its own board and budget;
(c) some combination of the above plus the existence of a broad-based policy-making and coordination body (e.g., a national agricultural research council). Variations of this model depend upon the relationship of the coordinating body to a general science council (where one exists) and its degree of control over the resource allocation process.

Which of these variants is the most appropriate or effective can only be discussed with reference to specific countries. However, even if not in a conclusive way, experience over the last 20–25 years indicates the relative weakness of the model that puts research as part of the line activities of ministries of agriculture and suggests that the use of broad representation boards at the policy-making level is more desirable. This is particularly true in terms of making the research system more accountable for the direction of its efforts and improving its capacity to generate more stable levels of support. Evidence for this comes from experience with the national research institutes in Latin America, as well as with the Commodity Boards in Malaysia, Sri Lanka, and other countries in Asia and Africa. Asian experience with the research council model provides further support for this, and it appears that this type of structure should be evaluated, especially with reference to the larger and more mature systems that require interactions among widely different sectors, such as universities, different types of research centers, and farmers' organizations, trade organizations, government.

Desirability of organizational autonomy. The degree of organizational autonomy affects the system's performance through its impact on areas like human resource development, financial management, and monitoring and evaluation as they relate to planning and program development activities. There must be enough institutional and administrative autonomy for policies and procedures to correspond with the specific characteristics and requirements of the research process. The problems and limitations of setting conditions of service and personnel policies for researchers within the general framework of the civil service and public administration regulations are well

documented. Similar problems arise with financial management practices that are usually designed to serve the need for control in large bureaucratic processes and are poorly suited to the needs of the research service, where amounts are comparatively small, and flexibility and timely expenditure are important. Furthermore, in many cases the administration of funds (actual disbursements) operates through different channels from research policy and program definition and implementation. This makes monitoring and evaluation difficult if not meaningless and seriously diminishes the strength of the planning process.

To solve these problems, the research system must be able to establish policies and procedures that reflect the needs of research. This is usually better accomplished in organizational structures having a fair degree of autonomy.

Centralization vs. decentralization. Another structural feature which affects the operation and performance of the research system is the degree of centralization.

The concept of centralization-decentralization can be applied at the system level, over the number of independent organizations or at the organizational level, over the decision-making processes and units within one organization. Here we refer mostly to the latter.

Since agricultural research is highly location specific, activities must be developed at the agroecological sites where the problems are, and decision-making processes must reflect those conditions in program development. This requires a high degree of operational and decision-making decentralization. However, other factors imply the need to centralize those same aspects. Some services and support activities are performed more effectively and with a more efficient use of resources when centralized. With some, such as library and documentation, certain laboratory facilities, and some disciplinary work, there are obvious economies of scale to consider. Furthermore, to direct activities effectively toward national priorities, to coordinate programs and budgets, to maintain a stable and continuous flow of funds and keep effective communication with political levels, some centralization is needed. Thus, the organizational structure must balance the opposing forces, allowing operating units to maintain enough initiative to effectively influence program development and implement work programs.

The need to facilitate an inter-disciplinary approach. A crucial problem facing research institution organization is the permanent conflict between the organization of the agricultural sciences by discipline and the commodity or farming-systems focus needed for technology development.

Development and maintenance of a long-term research capacity is better served by internal structure according to discipline. This facilitates scientific linkages and the development of peer review and personnel evaluation systems. It also offers greater flexibility for program reorientation and adjustments, but at the risk of program fragmentation from the pursuit of disciplinary priorities not necessarily related to real production problems. However, technological problems and needs are defined along commodity lines or with reference to specific farming systems and require an inter-disciplinary approach. Furthermore, effective communications with users, essential for developing an appropriate program focus, and testing proposed technologies is not facilitated by a disciplinary organization. The product/commodity/system focus is also more effective in relating research to the other agricultural policy instruments and to development efforts in general.

Several alternatives have been used to draw together the two perspectives. The farming systems approach and different organizational schemes – internal structure by discipline; program definition by commodity or system – have been tried with varying degrees of success in different situations. At this time, it is still difficult to make definitive judgments about them. However, we should stress that they are not exclusive alternatives, since effective

research with a farming systems perspective must rely upon and collaborate with conventional discipline-oriented and commodity-focused research efforts. Two aspects to consider in selecting the strategy for meeting the interdisciplinary needs of agricultural research are the system's capacity and the characteristics of the farming community it has to serve. In the case of larger systems serving commercial agriculture and specialized farmers' situations, a discipline/commodity matrix organization appears to be an effective option. As we move toward systems more oriented toward subsistence multiproduct farming situations, there is a greater need for more holistic views, such as the farming system approach.

The relationships detailed in this section are important for the development of strong and effective national research capacities. They are, however, quite general and must be examined in the context of each case, since they will assume different values, depending on national characteristics and on the size and level of development of the research system. For instance, because of the proportionately higher administrative costs involved, only small degrees of autonomy are possible in small systems. At the same time, the quantity and quality of available human resources limits the degree of decentralization that can be introduced at any particular time.

V. SUMMARY

Successful national agricultural research systems result from positive and mutually reinforcing interactions between three groups of variables: the policy environment; a set of essential operational processes which are common to all research systems; and the system's organizational structure.

The policy environment defines the stage and, in a certain sense, the limits for the research effort. Here priorities and resources, in quality and quantity, are defined, or should be, and all of the complementary policy definitions and actions necessary for the potential benefits of research to be realized are brought together. The essential processes govern the system's research capacity. They include those actions necessary for acquiring and transforming resources (inputs) into the expected research results (products). The organizational structure provides the context for the performance of the specific processes, and also the mechanisms for relating research to its policy and social environment. In each of the three previous sections, we highlighted the dimensions and characteristics of each of these three domains and some of the critical considerations that affect the interactions between them.

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