PRIORITIES FOR AGRICULTURAL RESEARCH IN LATIN AMERICA AND THE CARIBBEAN

Editor: Eduardo Lindarte

PROGRAM TO IDENTIFY PRIORITIES
AND MECHANISMS TO COORDINATE AND MANAGE
REGIONAL INVESTMENT AND AGRICULTURAL TECHNOLOGY
DEVELOPMENT PROJECTS
- PHASE I -

PRIORITIES FOR AGRICULTURAL RESEARCH IN LATIN AMERICA AND THE CARIBBEAN

EDITOR:

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April, 1998

The views expressed in this book are those of the authors and do not necessarily reflect those of IICA.

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FOREWORD

Since the 1970s, there has been growing interest in Latin America and the Caribbean (LAC) in terms of multinational agricultural research. In the late 1960s and early 1970s, the creation of three international centers of the Consultative Group on International Agricultural Research (CGIAR) —the International Center for Tropical Agriculture (CIAT), the International Potato Center (CIP) and the International Maize and Wheat Improvement Center (CIMMYT)— along with the impact of these centers on national research organizations or entities, once again raised the question of the relationship between the actors.

The 1980s ushered in a new form of cooperation and interchange between national actors, which focused attention on the transnational level, in particular on the subregional multithematic networks of national agricultural research institutes (NARIs) and horizontal, reciprocal, cooperative research and technology transfer programs (PROCIs). These include the Cooperative Program for the Development of Agricultural Technology in the Southern Cone (PROCISUR), the Cooperative Agricultural Research and Technology Transfer Program for the Andean Subregion (PROCIANDINO) and, most recently, the Regional Program to Upgrade Agricultural Research on Staple Grains in Central America and Panama (PRIAG) and the Cooperative Program on Research and Technology Transfer for the South American Tropics (PROCITROPICS).

Other processes of evolution and change have chipped away at the long-standing regional research model developed after World War II. Originally built around the NARIs, this model was later extended to include the concept of national systems. These processes include the following:

1. The factors associated with the demand for know-how have led to an enormous expansion and diversification in scientific and technological requirements. Population growth, rapid urbanization, economic growth, and industrialization based on import substitution all fueled the diversification and expansion of agricultural production, and the settling and incorporation of new agroecological areas. This brought more heterogeneity in the scale and systems of production and, subsequently, competitive pressures resulting from economic opening and the creation of tariff unions.

2. On the other hand, the new need to ensure the sustainability of complex production systems and the socioeconomic, organizational, and management aspects of both production and technology led to growing diversification allied to the new scientific-

technological paradigms such as biotechnology and informatics. Other new fields and problems related to genetic resources, biodiversity, biosafety and, increasingly, intellectual property also emerged. At a more general level, the agroindustrialization of agriculture is fueling the development of innovative systems that, while highlighting the pivotal and strategic role of technological know-how, are altering its nature, sources, and insertion into production. One of the net results has been that the interaction between technological actors, and between them and the productive sector, has become more complex and demanding.

3. With regard to supply, national government-funded institutes were impacted by the structural adjustment processes and the downsizing of the state apparatus and its functions. As a result, they were no longer in a position to continue expanding their efforts, as they had in previous decades, to meet new demand. Although this was offset in part by the emergence of and increase in new actors and types of national entities (e.g., private research centers and universities), projections of the needs and the demand for know-how have outstripped countries' capacity to respond.

4. The fact that much of the technology produced (especially agronomic and management-related outputs) evidently pertains to the public domain, the focus of most of the NARIs' efforts, means that research expenditure generates what economists call "externalities" or outputs that are of use to third parties. Technologies can have alternative applications or a spillover effect from which other countries benefit. Given the significant agroecological and socioeconomic similarities between countries in the region, this is often the case.

   This juxtaposition of an increase in the demand for technology and know-how and reduced or frozen capacities has resulted in the inefficient fragmentation of available expertise. International collaboration can therefore go a long way toward solving the problem, as the distribution and pooling of efforts increases total capacity.

5. Cooperation also offers other potential benefits, such as economies of scale through the formation of critical mass for addressing problems and the introduction of more efficient institutional arrangements than the existing research and transfer mechanisms.

6. Transnational cooperation works not only for public goods but also as a mechanism for the negotiation and sharing of private goods. Germplasm is a case in point. Lastly, national institutions and financial entities such as the Inter-American Development Bank (IDB) and technical cooperation agencies like IICA have emphasized the importance of multinational cooperation on research.

   While transnational cooperation in the region has had a significant impact through international and regional centers such as the Tropical Agriculture Research and

Training Center (CATIE) and the Caribbean Agricultural Research and Development Institute (CARDI), as well as different networks such as those of the United Nations Food and Agriculture Organization (FAO), the Inter-American Institute for Cooperation on Agriculture (IICA), and the PROCIs, the scale of these efforts is still relatively small in comparison with the combined capacity of all the countries. There are a number of reasons why the growth of the transnational effort has been limited. These include the inertia and weight of the traditional reliance on national endeavors, a certain resistance to change, and the dearth of resources, mechanisms, and guidelines for efforts of this kind.

At several meetings, national and regional entities and the IDB discussed the importance of and urgent need to establish priorities that would pave the way for new developments. In late 1992, this resulted in an IICA/IDB Project (ANT/SF-3410). This project was executed jointly by the IDB (which provided funding, counterpart personnel, and coordination) and a team of IICA experts through the former Program II: Technology Generation and Transfer[1] . Under the direction of Dr. Eduardo Trigo, in association with a group of technical experts from the region, this project was entrusted with laying the foundations for the effort.

The project personnel recognized that the work posed a double challenge. It presupposed the need for a substantial technical effort to identify the areas where joint action would be useful or beneficial to those involved, and to the region as a whole. It also called for institutional processes and mechanisms that would make it possible to discuss and reach agreement on effective decisions on priorities based on the above. The present book, prepared by IICA External Consultant Manoel Tourinho, contains much of the work carried out to achieve both objectives.

It includes a proposal for an interagency consultative mechanism to define research priorities and resources. In addition to describing how the mechanism would operate, it deals with the complex issue of relations between the levels (i.e., regional, subregional, national, and subnational), agencies, and participants involved in the priority-setting process. An innovative scheme is proposed that would harmonize the subnational and national levels with the subregional and regional levels.

This proposal was discussed at a joint meeting of PROCIANDINO, PROCISUR, and PROCITROPICS in Santa Cruz, Bolivia, in December 1993. The meeting was also attended by representatives from the international and regional centers, the IDB, IICA,

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1 The Directorate of Science and Technology, Natural Resources and Agricultural Production (Area of Concentration II) executes the actions that were previously the responsibility of Program II: Technology Generation and Transfer. Since this document was completed at the end of 1993, no reference is made to IICA's new institutional structure as provided for in Executive Order 01/94 of October 12, 1994, which sets out the guidelines established in the 1994-1998 Medium Term Plan.

and the International Service for National Agricultural Research (ISNAR). The ideas put forward were the subject of lively discussion and there was clear consensus on the importance of the subregional level and the PROCIs, which would be expanded to include new actors. These strategic bodies would be responsible for identifying and reaching agreement on transnational priorities.

The meeting paved the way for a second phase or project that will identify and negotiate specific transnational priorities for the region and, over the longer run, will address the methodological training of technical staff and the generation of appropriate information systems.

In publishing this document, IICA is pleased to be able to contribute to the identification of research priorities and resources.

This book summarizes much of the work done to meet both challenges.[2]

Chapter 1 presents the results of the institutional inventory of resources, capabilities, and areas of concentration in agricultural research entities in Latin America and the Caribbean. A comparison of these results with those obtained by the International Service for National Agricultural Research (ISNAR) in the early 1980s reveals a serious problem in the NARIs that threatens the development of the capabilities that will be needed if the countries of the region are to meet the challenges of innovation. It also shows that several institutions are involved on multiple work fronts.

In Chapter 2, Philip Pardey and Stanley Wood discuss the nature and problems of agroecological zoning in the region, as well as current efforts and opportunities in this field. They offer a method for demarcating, by homogeneous geographic areas, the effects of technologies and technology spillover. This will make it possible to predict the direct impact of technology more accurately, to formulate solutions to specific limitations, and to evaluate more clearly the transfer of research findings. The authors propose a participatory plan for work among several entities, with a view to improving zoning efforts.

Chapter 3 offers a summary of the work done by a technical group made up of representatives of five institutions in reviewing the model developed by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) for prioritizing agricultural research. The group identified weaknesses in the model in terms of its coherence and applicability, and its failure to consider the future. On the basis of these weaknesses, the group described and partially tested, for purposes of illustration, an adjusted version of the prioritization model.

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2 Other efforts are described in the book *Propuesta de un mecanismo de consulta interinstitucional para definir prioridades y recursos para la investigación agropecuaria* (IICA 1995), written by Manoel Tourinho, an external consultant.

In Chapter 4, Rafael Posada and others describe an exercise carried out in Colombia, Ecuador, and Venezuela to identify priorities, as well as the results of same. On the basis of previous experiences, five commodities of interest in the subregion were given priority: rice, corn, cassava, tropical fruits, and livestock. Also, a methodology for selecting one priority topic related to each commodity was implemented. Project profiles were then formulated and an institutional organization mechanism was proposed for structuring and executing each one jointly.

In Chapter 5, Hector Medina Castro presents the results of a study aimed at identifying agricultural research priorities by commodities in the countries of Central America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) between 1990 and 1992, by applying a methodological approach or scoring model. Basic elements are identified for analyzing the priorities and putting them in context, the specific methodology used in each country is formulated, and the results obtained are presented.

Chapter 6 provides a summary of the work done by a team of representatives from the National Institute of Agricultural Technology (INTA) of Argentina, the Brazilian Institute of Agricultural Technology (EMBRAPA), and IICA, under the technical coordination of Eugenio Cap, to develop and test the production of agricultural surpluses by technology (PEAT) model. This is an innovative instrument for the ex-ante evaluation of alternative lines and strategies of research, providing bases for maximizing the allocation of the internal and external resources of research institutes.

The PEAT methodology differs significantly from that used in previous models in that it supposes the existence of several levels of technology at the farm level and recognizes several levels of aggregation. The PEAT methodology was applied to four lines of wheat research common to INTA and EMBRAPA, and generated different cost-benefit options depending on the type of organization adopted. The results in particular, and the methodology in general, generate a base for creating institutions aimed at improving the allocation of resources for research, such as cooperation among entities and competitive bidding.

Together, these research efforts provide criteria for the complex topic of setting priorities, which involves, in addition to methodologies, information and qualified technical teams, issues related to institutional organization, decision making, and political will. IICA is pleased to present these works and to make them available to interested readers.

Eduardo Lindarte

Chapter 1

RESOURCES, CAPABILITIES AND PATTERNS OF CONCENTRATION IN AGRICULTURAL RESEARCH INSTITUTIONS: RESULTS OF AN INVENTORY IN LATIN AMERICA AND THE CARIBBEAN

Eduardo Lindarte

CONTENTS

ACKNOWLEDGEMENTS

This inventory, like so many other projects, is the result of efforts by many people. The design of the inventory and formulation of the questionnaire were the responsibility of the following team (listed alphabetically): Eduardo Lindarte, Julio Palomino, and Luis Romano. They were aided by Eugenio Cap, Luis Macagno, Héctor Medina, and Elmar Rodriques da Cruz.

The questionnaires were collected by the executive secretaries of the Regional Program to Upgrade Agricultural Research on Staple Grains in Central America and Panama (PRIAG) (Porfirio Masaya), the Cooperative Agricultural Technology Research and Transfer Program for the Andean Subregion (PROCIANDINO) (Nelson Rivas), the Cooperative Program for the Development of Agricultural Technology in the Southern Cone (PROCISUR) (Amelio Dall'Agnol). Besides these, other help was provided by the Agricultural Development Foundation of the Dominican Republic (FDA) (Altagracia Rivera), and the Caribbean Agricultural Research and Development Institute (CARDI), as well as Jan Hurwitch, IICA Representative in Haiti at that time.

Robert Castro was in charge of designing the database and processing the statistics. Leticia Gimenez transcribed the data and provided secretarial support for this report. Alfonso Campos collaborated in tabulating the data.

INTRODUCTION

The present document presents the main results of a project entitled Inventory of Resources, Capabilities, and Areas of Concentration in Agricultural Research Institutions in Latin America and the Caribbean (LAC) carried out under the IICA/BID Agreement "Program for the Identification of Technical Agricultural Investigation and Development on the Regional Level."[1] The objective of the inventory was to identify and update knowledge on the most important capacities, resources, and work areas in the regional research system, as well as on major technological limitations in agriculture. A complementary objective was to identify the human capabilities and experience relevant to prioritizing research.

METHODOLOGY

Population and Unit of Analysis

Agricultural and forestry research institutions in Latin America constituted the unit of analysis for this study. This population is comprised of various layers or subpopulations: (a) national agricultural research institutes (NARIs) or their functional equivalent (central research programs), (b) official public institutions related to natural resources or forestry research, (c) other public agricultural research institutions, (d) universities, foundations, and private, semiprivate, or union organizations that carry out agricultural research, and (e) regional and international research centers.

Due to the broad scope of the inventory (the entire LAC area) and the short amount of time available for executing the inventory, it was not feasible to identify the population prior to designing the method of collecting the information. Rather, this stage was combined with the field stage, which was the responsibility of the organizations and individuals in charge of collecting the information.

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1 The first draft of this work was presented at the end of 1993 under the title "Results of the Inventory of Resources, Capacities, and Areas of Concentration in Agricultural Research Institutions in Latin America and the Caribbean."

Instrument

In December 1992, a team of experts in priority setting from the Colombian Agricultural Institute (ICA), the Ecuadorean National Agricultural Research Institute (INIAP), the INTA of Argentina, the Brazilian Agricultural Research Company (EMBRAPA), and IICA Headquarters in Costa Rica designed the basic questionnaire and instructions for its application. The questionnaire was then edited and translated into English by the Project Coordination Office in Costa Rica. The questionnaire included five chapters covering the following areas: (a) institutional identification, (b) human and financial resources, (c) programmatic work areas, (d) technological restrictions or limitations, and (e) work carried out on setting priorities.

Collection

Once the questionnaires were distributed, their collection was organized based on the relationships established by IICA with various agricultural research institutions in LAC. CARDI gathered the information in the Caribbean. PROCISUR, PROCIANDINO, and PRIAG identified those responsible for national distribution and collection for the southern, Andean, and central areas, respectively. The FDA gathered the information in the Dominican Republic. The Project Coordination Office in Costa Rica channeled the request for information to Mexico (directly and by way of their representative), and to Haiti through that country's IICA representative. It also directly channeled the collection effected in the following international centers: the Tropical Agriculture Research and Training Center (CATIE), the International Center for Tropical Agriculture (CIAT), the International Maize and Wheat Improvement Center (CIMMYT), and the International Potato Center (CIP).

Processing

The questionnaires were processed at IICA Headquarters in Costa Rica and stored in a database from which the tables and results presented in this report were generated.

Coverage

The coverage of this inventory can be considered either according to the kind of institutions covered or the area in which the institutions are located (Caribbean, central, Andean, and Southern Cone). Table 1 summarizes the information for both variables.

The analysis according to kind of informant institution showed that the majority of sources were NARIs, in spite of the fact that responses were not received from the National Forestry and Agriculture Research Institute (INIFAP) of Mexico and some Caribbean countries. Except for CIMMYT, coverage of international and regional centers was complete, including the six CARDI national offices. It would have been desirable to include international centers headquartered outside the LAC area but who carry out work within the region, such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) located in India and the International Rice Research Institute (IRRI) located in the Philippines.

Table 1. Number of research institutions according to kind and location.

Kind of Institution	Central	Caribbean	Andean	South	Totals
NARIs/cent. res. progs.	6	3	5	5	19
Ofic. nat. rec. instits.	4	2	4	1	11
Other public instits.	9	1	1	14	25
Univs./semipriv. instits.	10	2	1	–	13
Reg. or int. centers	1	6	2	–	9
Totals	30	14	13	20	77

Note: Five CARDI dependencies were classified as "regional centers."

The degree of coverage, while less clear in the other categories, is at least partial. Coverage of official natural resource institutions is selective. The same occurs in the other public institutions category, which includes data from 14 state research companies in Brazil. In the universities and semiprivate institutions category, only the University of Molina and the National Agrarian University of Nicaragua are included under universities. The inventory didn't intend to cover universities, due to the particular methodological difficulties posed by evaluating their contributions and compiling the respective data, which would have required a special design and more time. Nevertheless, it is important to recognize that their contribution is increasing in many countries. In many cases, private institutions include institutional structures that combine the public and private (semiprivate institutions) and many research foundations. In spite of this, coverage is only partial.

By zone, the greatest coverage was achieved in Central America with an average of five institutions per country. This is a high result if the number of questionnaires per country, population, and probable absolute volume of research activities undertaken in the region are taken into account. The large number of institutions in this region classified as private should be emphasized. These reflect the gradual disintegration of the old official programs and NARIs and efforts to move toward generalized privatization. Since the inventory was carried out, research within the INTA in Nicaragua has been reconstituted, the Agricultural Technology Center (CENTA) has been made more autonomous and financially strong, and several changes were carried out in the Ministry of Agriculture and Livestock of Costa Rica.

The zone that perhaps received the least coverage was the Caribbean. In addition to the English-speaking islands, this zone also includes the Dominican Republic and Haiti. In the English-speaking countries, coverage just includes the CARDI dependencies and the Ministries of Agriculture of Belize and Saint Vincent and the Grenadines, and doesn't include the ministries or NARIs of the large countries such as Guyana, Suriname, and Jamaica. The rest of the questionnaires classified as coming from NARIs in the Caribbean correspond to Haiti and the Dominican Republic.

Limited but essential coverage of the Andean area was achieved, which includes the NARIs, forestry institutions, and two international centers: the CIP and CIAT. However, foundations, union organizations, and other important institutions in the region were largely excluded (for example, the Coffee Research Center [CENICAFE] and the Sugarcane Research Center [CENICANA] in Colombia). Coverage in the Southern Cone mainly consisted of the NARIs; in Brazil more than a dozen state research companies were also included. As in the Andean area, private and semiprivate institutions weren't covered.

Table 2 illustrates the number of responses by country. Brazil, Nicaragua, and Costa Rica contributed the greatest number.

Table 2. Number of responses from research institutions by country.

Countries	Number of institutions
Costa Rica	9
Nicaragua	7
Guatemala	3
Honduras	4
Panama	3
El Salvador	4
Barbados	1
Haiti	3
Trinidad and Tobago	1
Guyana	1
Saint Vincent and the Grenadines	2
Belize	2
Dominica	1
Antigua and Barbuda	1
Dominican Republic	2
Colombia	3
Venezuela	3
Ecuador	2
Peru	2
Bolivia	3
Argentina	1
Brazil	14
Chile	2
Paraguay	2
Uruguay	1
Total	77

RESULTS

Human Resources

The inventory identified a total of 43,854 people in research institutions, 10,724 of whom were reported to be research personnel (Table 3). This number is greater than the 8,522 people formally classified as "researchers."[2] Out of this last group, 15.8% have a doctorate, 38.5% a master's degree, and the rest, 45.7%, a basic university degree (Table 4). In other words, almost half of the agricultural researchers in the LAC region have only a basic university degree, a remarkably low educational level for this activity.

When institutional location of these researchers is examined, the inventory found that 64.5% are concentrated in the NARIs, distributed by degree level (basic university, masters, and doctoral) in almost the same proportion as above. At the other extreme, only 2.4% of the researchers are located in the official natural resource institutions, and 5.1% in the universities and semiprivate institutions (although it should be remembered that the latter group of institutions are underrepresented in the coverage). Likewise, some predictable asymmetries can be observed in relation to the distribution of doctoral-level professionals. Although international centers staff only 9.0% of the researchers, they have 13.4% of all the researchers with doctorates, and natural resource institutions have only 0.5%.

Differences are notable by region. Almost 60% of the researchers are in the Southern Cone. At the other extreme, only 1.3% are located in the Caribbean. Just under 40% are concentrated in Central America and the Andean countries.

In Central American, Caribbean, and Andean countries, approximately 11% of the total number of researchers hold doctoral degrees; in the Southern Cone this figure goes up to 19%. Almost two-thirds of the researchers in Central America hold only a basic university degree. The average size of the research institutions, measured by number of researchers, is smallest in the Caribbean, followed by Central America, then the Andean countries, with the largest average size in the Southern Cone.

Finally, the inventory found that 64.0% of the researchers engage in applied research, 25.5% in adaptive research, and 10.5% in basic research (Table 3). This distribution should be taken as a tentative approximation.

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2 The question on research personnel in the questionnaire asked for a breakdown of numbers with a basic university degree, master's, or doctorate. These were designated as "researchers" in this work. The majority of informants understood the question correctly; the result is that in almost all cases total researchers are less than or equal to research personnel. When this number is less, it reflects that the "research personnel" category includes person without a university degree. Discrepancies occur in six cases, however. The most substantive corresponded to Argentina. On the INTA questionnaire, only technical personnel were reported under total personnel, which includes 1015 in research, 252 in extension, and 108 in other functions. Under "researchers," the technical personnel were broken down by highest education level, leaving out 60 whose degrees weren't easily compatible with the subcategories, which is to say, a total of 1315 people, or an overestimate of 300 researchers.

Table 3. Personnel in LAC institutions by subregion.

	Subregions				
	Caribbean	Central	Andean	South	Total
Total personnel	820	10,579	9,111	23,344	43,854
Research personnel	118	1,538	3,386	10,734	
Research personnel in commission	20	72	164	604	860
Researchers					
with basic univ. degree	43	861	1,228	1,762	3,894
with master's	54	306	600	2,321	3,284
with Ph.D.	12	141	239	955	1,347
Total no. researchers	109	1,308	2,067	5,038	8,522
% by region	1.3	15.3	24.3	59.1	100
% in basic research	6.6	15.5	25.8	10.0	64.0
% in applied research	62.8	45.6	67.2	63.0	25.5
% in adaptive research	30.6	38.8	17.0	27.0	10.5
Total percentages	100.0	100.0	100.0	100.0	100.0
Average no. of researchers by instit.	7.8	43.6	159.0	252.0	110.7
by NARI	6.3	85.8	286.4	706.0	289.2
Average no. of Ph.D.'s					
by instit.	0.9	4.7	18.4	47.8	17.5
by NARI	0	3.2	21.8	149.8	46.2
by reg./int'l. center	0.7	49.0	63.5	0	20.0

Taken together, these figures reveal subregional contrasts between the Southern Cone and the other areas, as well as a notable weakness in research capacity due to the low number of personnel with the highest training levels.

It is important to evaluate the impact resulting from coverage problems in the Caribbean, the INIFAP, and the CIMMYT (Mexico). A World Bank Report (World Bank 1992:5) on the CARICOM (Caribbean Community) countries estimated that in 1992 a total number of 320 researchers were spread out over 25 countries (based on 1990-91 data). With respect to the total registered by the inventory, this suggests an omission of approximately 200 researchers in the region. On the other hand, in 1992 the INIFAP had 1716 professionals involved in research, including 137 in management and administration. Of this total, 890 were university professionals, 590 held master's degrees and 236 held doctoral degrees (Alarcón and Elías Calle 1992:6). Based on the CIMMYT report for 1993, we estimate the number of researchers linked to Latin America in this institution at 75 (CIMMYT 1994).

Looking at these figures, it is possible to conservatively infer an underestimation of approximately 2000 researchers in these institutions. This would indicate a total of at least 10,500 researchers for LAC. These quantitative adjustments have not been incorporated into the tables in this chapter, but they are included in the discussion and results of the final part, which presents some considerations on evolution.

Table 4. Number of researchers in LAC according to academic degree and kind of institution in which employed.

Kind of institution		Basic degree	Master's	Ph.D.	Totals	
					Quantity	%
NARIs/central research programs		2,497	2,122	877	5,496	64.5
Official natural resource institutions		177	22	7	206	2.4
Other public institutions		584	825	212	1,621	19.0
Universities and semi-private institutions		222	138	71	431	5.1
Regional and international centers		414	174	180	768	9
Totals	Quantity	3,894	3,281	1,347	8,522	—
	(%)	45.7	38.5	15.8	—	100

Financial Resources

Tables 5 and 6 present, respectively, the research institutions' expenditures and income budgets in 1992, with local currencies converted to US dollars at the current rate for that year as stated by the International Monetary Fund (IMF).

Total research expenditures reached US$588 million, of which 68.6% corresponds to the Southern Cone area and 0.5% to the Caribbean. In terms of distribution by use, 65.4% is allocated to salaries, 20.7% to operating costs, and 13.9% to investments. If the investments are omitted, in order to contrast salary expenditures with operating cost expenditures, the regional percentage allocated to salaries rises to 75.9%, which leaves a relatively small percentage (less than 25%) for operating costs. This situation is particularly accentuated in the Andean and southern countries, in which the percentages spent on salaries reach 76.5% and 80% respectively. This division is also evident in the NARIs (79.9%), and especially in the Southern Cone (81.5%).

Income for this year (1992) reached US$630 million, 107.2% of reported expenditures. Official sources provided 69.1% of income, followed by external sources at 15.0%. This proportion rises to 82.4% in the Southern Cone area, which reflects the exclusive coverage of official institutions in that region.

The distribution of funding sources by kind or type of institution is interesting. The NARIs depend on governments for 79% of their income, while external resources (11%) and their own resources (9%) make up the other fifth. Natural resource institutions, currently receiving much attention, obtain 21% and 15% of their income from external and their own resources, respectively, and only 54% from governments. On the other hand, semiprivate institutions, universities, and regional and international centers obtain approximately 90% of their income from external sources and project funding.

Regarding omitted institutions, the World Bank (1992) estimated the total cost of agricultural research carried out in the CARICOM countries in 1992 to be US$24 million, or almost US$21 million more than the US$3.3 million obtained in the inventory. For the INIFAP in Mexico (again for 1991) the total is US$75 million (approximately US$83.6 million in 1992),[3] of which 71% corresponds to salaries (Alarcón and Elías Calle 1992:6). The CIMMYT reported that in 1992 it spent US$33.7 million (CIMMYT 1993:17).

In synthesis, an underestimation of US$138 million for the year 1992 was obtained. The adjusted total over this base would then go from US$571.1 million to US$709 million. As in the case of the underestimation of personnel, this adjustment is not incorporated into Tables 7 and 8, but is taken into account in the analysis of evolution.

Expenditures per Researcher

By combining the budget information with the number of researchers (Tables 3 and 5), expenditures per researcher by type and region are obtained. It can be observed in Table 7 that the average amount spent per capita, including investment, is US$69,010, and ranges from US$29,559 in the Caribbean to US$80,051 in the Southern area. If investment is excluded, the regional average is US$59,413 and varies between US$28,406 in the Caribbean and US$71,354 in the Southern area.

The low results obtained in the Caribbean probably reflect coverage deficiencies in this subregion. If we take instead the World Bank figures of US$24 million (320 researchers), the average is US$75,000 per person. This amount seems to better represent the high costs of the Caribbean and is close to the average for the Southern Cone area.

3 The adjustment was based on the implied deflator of the gross domestic product (GDP) in the United States provided by the IMF, which yielded a corrector of .89695.

Table 5. 1992 institutional expense budgets for research in LAC, according to type of institution, location, and purpose (in US$).

Type of institution	Central	Caribbean	Andean	Southern	Total
			Salaries		
NARIs/cen. res. prog.	10,603,993	374,660	39,974,497	247,865,451	298,818,601
Ofic. nat. res. instits.	261,171	70,000	561,868	514,473	1,407,512
Other pub. instits.	1,976,938	597,264	2,333	39,205,331	41,781,866
Univs./semipriv. instits.	5,805,374	42,411	315,900	—	6,163,685
Reg. or int'l. centers	9,148,558	1,010,592	26,022,000	—	36,180,675
Total	27,795,558	2,094,928	66,876,598	287,585,255	384,352,339
			Operating costs		
NARIs/cen. res. prog.	5,483,783	227,885	13,425,263	56,212,762	75,349,694
Ofic. nat. res. instits.	291,456	9,411	231,700	388,962	921,531
Other pub. instits.	1,285,685	70,880	3,846	15,295,353	16,655,764
Univs./semipriv. instits.	3,913,623	29,088	100,912	—	4,043,625
Reg. or int'l. centers	7,591,893	664,078	16,742,000	—	24,997,972
Total	18,566,442	1,001,344	30,503,723	71,897,077	121,968,586
			Investments		
NARIs/cen. res. prog.	10,368,792	28,081	17,932,757	35,615,956	63,945,586
Ofic. nat. res. instits.	88,020	—	364,332	57,351	509,703
Other pub. instits.	2,247,188	—	1,538	8,142,179	10,390,907
Univs./semipriv. instits.	2,453,384	—	—	—	2,453,384
Reg. or int'l. centers	2,089,465	97,629	2,300,000	—	4,487,095
Total	17,246,851	125,711	20,598,627	43,815,487	81,786,676
			Total expenditures		
NARIs/cen. res. prog.	26,456,569	630,627	71,332,517	339,694,169	438,113,882
Ofic. nat. res. instits.	640,648	79,411	1,157,901	960,786	2,838,746
Other pub. instits.	5,509,812	668,144	7,717	62,642,863	68,828,538
Univs./semipriv. instits.	12,172,383	71,499	416,812	—	12,660,696
Reg. or int'l. centers	18,829,440	1,772,300	45,064,000	—	65,665,741
Total	63,608,853	3,221,983	117,978,949	403,297,818	588,107,603

Table 6. Research institution income according to type, area, and source (US$).

Type of institution	Areas: Central	Caribbean	Andean	Southern	Total
	Income from governmental sources				
NARIs/cen. res. prog.	11,741,449	413,864	56,276,169	306,410,405	374,841,887
Ofic. nat. res. instits.	369,948	0	358,893	795,000	1,523,841
Other pub. instits.	1,202,061	597,264	509,231	52,221,407	54,529,963
Univs./semipriv. instits.	4,055,248	0	83,363	0	4,138,611
Reg. or int'l. centers	0	619,711	0	0	619,711
Total	17,368,706	1,630,839	57,227,656	359,426,812	435,654,013
	Own resources				
NARIs/cen. res. prog.	1,669,609	209,176	8,554,343	30,818,415	41,251,543
Ofic. nat. res. instits.	0	0	335,861	103,786	439,647
Other pub. instits.	3,377,584	69,000	0	6,048,845	9,495,429
Univs./semipriv. instits.	1,718,755	3,906	150,638	0	1,873,299
Reg. or int'l. centers	4,321,907	9,624	2,100,000	0	6,431,171
Total	11,087,855	291,346	11,140,842	36,971,046	59,491,089
	External resources				
NARIs/cen. res. prog.	12,938,681	0	7,202,761	31,190,791	51,332,233
Ofic. nat. res. instits.	269,704	71,600	186,604	62,000	589,908
Other pub. instits.	1,011,408	1,880	0	1,231,719	2,245,007
Univs./semipriv. instits.	7,885,290	87,594	182,813	0	8,155,697
Reg. or int'l. centers	15,227,533	548,694	16,464,000	0	32,240,227
Total	37,332,616	709,768	24,036,178	32,484,510	94,563,072
	Other income				
NARIs/cen. res. prog.	0	7,563	6,588,351	5,051,807	11,647,721
Ofic. nat. res. instits.	0	0	278,719	0	278,719
Other pub. instits.	0	0	0	2,306,448	2,306,448
Univs./semipriv. instits.	99,963	0	0	0	99,963
Reg. or int'l. centers	0	139,798	26,500,000	0	26,639,798
Total	99,963	147,361	33,367,070	7,358,255	40,972,649
	Total income				
NARIs/cen. res. prog.	26,349,740	630,602	78,621,624	373,471,418	479,073,384
Ofic. nat. res. instits.	639,652	1,600	1,160,076	960,786	2,832,114
Other pub. instits.	5,591,053	668,144	509,231	61,808,420	68,576,848
Univs./semipriv. instits.	131,579,255	91,500	416,813	0	14,267,568
Reg. or int'l. centers	19,549,440	1,317,468	45,064,000	0	65,930,908
Total	65,889,140	2,779,314	125,771,744	436,240,624	630,680,822

Table 7. Expenditures per researcher in 1992 by area and type of institution (US$).

Region	Salaries plus budget	Total, incl. investment	Type of institution	Salaries plus budget	Total, incl. investment
Caribbean	28,406	29,559	NARIs	68,080	79,715
Central	35,445	48,163	Nat. res. instits.	11,306	20,728
Andean	47,112	57,077	Other public	36,050	42,460
Southern	71,354	80,051	Semipriv./univ.	23,683	29,375
LAC Region	59,413	69,010	Centers	79,660	85,502

Concentration of Effort

In recent years, IICA has entertained the hypothesis of an excessive dispersion of efforts in relation to available resources for carrying out tasks, especially within the NARIs. This is based upon observation of the increasing number of species under research in these institutions, especially up until the late 1980s. During this time there were often over 50 species covered, sometimes nearing 100. Added to this is the greater burden due to more agroecological zones and the distribution of work among an increasing number of research centers, stations, and farms, and a broader range of disciplines and themes.

In spite of its important implications, the hypothesis has not been tested. In order to explore this theme, the questionnaire included questions on the number of species studied in 1992, classified as annual crops, perennial crops, forest crops, pasture, land animals, or aquatic animals. The overall results are shown in Table 8. As can be observed, the average is particularly high (over 50) in the Southern Cone area. The NARIs register the highest number of species covered of the institutions, with the exception of the official natural resource institutions in the south.

When the average numbers of species covered in the different institutions are related to the average number of researchers in each type of institution, the results presented in Table 9 are obtained.[4] It shows that only the regional and international centers and the NARIs have four to five researchers available per species under study, and even this number appears low in terms of critical mass.

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4 Dividing both the averages, researchers per institution by species per institution, is not equivalent to dividing the total number of investigators by region by the total number of species reported per region, since the "n" of both does not coincide in all cases. More precisely, the same institutions did not always respond to both questions (on researchers and species). However, using the second method doesn't substantially alter the results: the biggest difference is found in the Andean area, where the average goes from 2.7 to 4.3.

Another reason for presenting the results in terms of an average of averages is that they have meaning seen as something that occurs within the institutions. In other words, the value of 1.5 for the Caribbean indicates that within the institutions covered in the region, there was an average of 1.5 researchers per species covered.

Table 8. Institutional mean of species studied in 1992 and the number of institutions involved, according to type and location.

Type of institution	Species									
	Subregions									
	Central		Caribbean		Andean		Southern		Totals	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
NARIs/cen.res. prog.	76	6	3	3	53	5	85	5	61	19
Ofic. nat. res. instits.	10	4	20	1	12	4	205	1	22	14
Other pub. instits.	2	7	11	1	9	1	69	13	42	22
Univs./semipriv. instits.	20	10	7	2	37	1	—	—	20	13
Reg. or int'l. centers	41	1	7	6	40	2	—	—	18	9
Totals	27	28	6	16	34	13	81	19	37	77

Note: (1) = mean number of species investigated by institution; (2) = number of institutions involved.

The mean numbers correspond to the sum of species in annual, perennial, forest, and pasture crops, and land and aquatic animals.

Table 9. Institutional averages of researchers per species under study according to type of institution.

Type of institution	Average
NARIs/cen. res. prog.	4.8
Ofic. nat. res. instits.	0.7
Other pub. instits.	1.7
Univs./semipriv. instits.	1.7
Reg. or int'l. centers	4.7
General	3.0

In conclusion, the results seem to suggest critical problems for research, particularly if the agroecological diversity of LAC is taken into account, which requires larger teams to manage the intrinsic complexity. This should be understood as a very tentative conclusion, however, due to the limitations of the indicator. Studying a diverse number of crops doesn't mean that the institution treats all of them with equal intensity. In that sense, the result would be consistent with a large number of species receiving only marginal attention, while concentration is focused on only a few. For a more definitive conclusion, it would have also been necessary to consider the intensity of attention devoted to each species, which would have required deeper research into the matter. In addition, interinstitutional cooperation in specific work areas or with certain species can at least partially compensate for the lack of internal teams with sufficient critical mass. Even with all these qualifications, however, the hypothesis of dispersion of efforts appears to hold in a preliminary manner.

AREAS OF CONCENTRATION

Program Areas

What are the profiles of concentrated endeavor in LAC research institutions? One answer appears by examining their programmatic work areas by category or species and discipline, the subject of this section. The following section will examine effort distribution in relation to experimental centers.

Tables 10, 11, and 12 show the distribution of existing programs by region, type of institution, and volume of research personnel. It is important to take into account that the results do not include the 2096 EMBRAPA researchers, for which program information was lacking. In addition, two other institutions did not report information on programs due to their different organizational structure. In some cases, when non university graduates were included or certain researchers aren't assigned to programs, the number of program personnel differs from the total number of researchers.

The majority of programs are in Southern Cone institutions, followed by Central America, which probably reflects the greater institutional coverage in the latter. Slightly more than a third of the programs are found in the NARIs, which have almost half the total researchers. If the lack of EMBRAPA data was taken into account, this difference would probably.be even greater and show that the NARIs have the highest average number of research personnel, with the exception of international centers.

In terms of overall distribution of areas and number of programs and personnel, the largest category is in animal management and production (12%-13%). This simply reflects that the category includes the majority of animal-related themes. In fact, if animal nutrition themes and half of the overall health efforts are added in, about 20% of the programs and researchers would be concentrated in this category.

The second largest area (8%-10%) is cereals and grains. Other large areas include those related to economic, social, organizational, and management themes; plant health; animal production; and fruits and vegetables—especially if roots and tubers are added.

The NARIs, account for over half the programs in cereals and grains, legumes, oilseeds, roots and tubers, and vegetables. Natural resource institutions stand out in silviculture, the other public institutions in agronomy and plant-breeding, and the universities and semiprivate institutions in animal production and management.

Table 10. Work areas of institutions (programs/disciplines) by location and quantity of researchers.

Program or discipline	Areas				Totals		Quantity of researchers	
	Central	Caribbean	Andean	South	N	%	N	%
Cereals & grains	14	3	17	30	64	8	666	10
Legumes	5	3	7	7	22	3	204	3
Oilseeds	5	—	7	15	27	3	257	4
Roots and tubers	2	5	7	6	20	3	216	3
Vegetables	7	5	5	14	31	4	392	6
Fruits	16	5	9	24	54	7	514	8
Coffee/sugarcane	1	1	3	6	11	1	165	2
Silviculture	12	6	21	15	54	7	182	3
Animal nutrition/pasture & fodder	6	15	6	7	34	4	186	3
Animal prod. & management	18	21	18	40	97	12	887	13
Soils/water/climate/irrigation	9	6	5	18	38	5	355	5
Plant & animal health and protection	27	5	6	22	60	8	473	7
Agronomy, plant-breeding	26	11	4	18	59	7	420	6
Crop & livestock improvement	13	2	13	20	48	6	382	6
Natural resources	10	—	5	17	32	4	394	6
Socioeconomic & related themes	25	7	11	22	65	8	578	6
Others	24	5	13	29	71	9	442	7
Totals: N	220	100	157	310	787	—	6.693	—
%	28	13	20	30	100	99	—	100

Table 11. Work areas at institutions (programs/disciplines) by kind.

Program or discipline		Type of institution: NARIs & cent. res.	Ofic. nat. resource instits.	Other public instits.	Univ. & semipriv. instits.	Reg. & intl. centers	Totals N	Totals %
Cereals & grains		37	—	23	3	1	64	8
Legumes		12	—	5	4	1	22	3
Oilseeds		15	—	9	3	—	27	3
Roots and tubers		12	—	7	—	—	20	3
Vegetables		16	—	8	7	—	31	4
Fruits		25	—	18	11	—	54	7
Coffee/sugarcane		4	—	7	—	—	11	1
Silviculture		8	33	7	5	1	54	7
Animal nutrition/pasture & fodder		9	—	7	14	4	34	4
Animal prod. & management		42	1	26	23	5	97	12
Soils/water/climate/ irrigation		14	—	15	6	3	38	5
Plant & animal health and protection		21	—	24	9	6	60	8
Agronomy, plant-breeding		10	5	28	9	7	59	7
Crop & livestock improvement		22	1	17	3	5	48	6
Natural resources		7	10	12	2	1	32	4
Socioeconomic & related themes		24	2	21	8	10	65	8
Others		22	2	30	13	4	71	9
Totals:	**N**	300	54	264	120	49	787	—
	%	38	7	34	15	6	—	100

Table 12. Research personnel and programs by type of institution and location.

Type of institution		Research personnel (1) and programs (2)											
		Subregions								Totals			
		Central		Caribbean		Andean		Southern		1		2	
		1	2	1	2	1	2	1	2	N	%	N	%
NARIs-central res. progs.		516	67	20	16	1432	10	1424	11	3392	49	303	38
Official nat. res. instits.		60	23	4	2	74	26	5	13	138	2	56	7
Other public instits.		215	66	23	11	1	1	1991	19	2229	33	268	33
Univs. & semipriv. instits.		397	66	67	44	23	11	—	—	487	7	121	15
Reg. & int'l. instits.		201	4	51	28	379	21	—	—	631	9	53	7
Totals	N	1388	226	165	101	1909	162	3415	312	6877	100	801	100
	%	20	28	2	13	28	20	50	39	—	—	—	—

INITIATIVES IN CENTERS AND STATIONS

The work carried out by research institutions can also be located in terms of their activities in centers and stations. The inventory sought to cover them in terms of their location by agroecological zone, number of researchers, and main work areas. For location by agroecological zone, the Consultative Group on International Agricultural Research (CGIAR) classification system was used, which is in turn based on the zones proposed by the United Nations Food and Agriculture Organization (FAO). The informants were asked to assign their centers to a category within the agroecological classification.

Table 13 shows the distribution of the 379 centers and 6148 researchers assigned to them by area and type of institution. More than half are concentrated in the Southern Cone area and almost a quarter in the Andean area. Seventy-five percent of all the centers belong to NARIs.

In Table 14 the centers' work areas are intersected with the agroecological zones in which they are found. The principal work areas in terms of plants are cereals and grains, temperate and tropical climate fruits, and oilseeds. The zones with the greatest concentration are the tropics and cold subtropics with winter rains.

Table 13. Experimental centers and associated researchers.

Type of instit.	Number of researchers							
	Subregions							
	Central		Caribbean		Andean		Southern Cone	
	Experim. research	Assoc. center	Experim. research	Assoc. center	Experim. research	Assoc. center	Experim. research	Assoc. center
NARIs/central research programs	133	29	19	7	1232	60	3253	74
Official natural resource institutions	12	8	—	1	40	11	—	—
Other public institutions	54	8	29	5	2	2	1002	128
Universities and semiprivate instits.	164	19	14	3	19	2	—	—
Regional and int'l. centers	—	—	10	7	165	15	—	—
Totals	363	64	72	23	1458	90	4255	202

Table 14. Work areas by agroecological zone in which the institution is located.

Work areas	Agroecological zones									
	Warm-arid semiarid tropics	Warm subhumid tropics	Warm humid tropics	Cool tropics	Semiarid subtropics (summer rainfall)	Subhumid subtropics (summer rainfall)	Cold-humid subtropics (summer rainfall)	Cold sub-tropics (summer rainfall)	Cold sub-tropics (winter rainfall)	Other responses
Cereals & grains	30	32	12	3	9	2	6	11	5	32
Legumes	12	14	4	–	1	2	–	3	3	16
Oilseeds	19	23	11	–	6	10	1	6	9	16
Roots and tubers	3	2	2	4	–	1	–	3	2	5
Vegetables	17	17	8	5	4	3	11	3	5	16
Fruits	25	12	29	3	4	3	10	6	12	19
Coffee/sugarcane	4	4	3	5	–	1	9	–	–	6
Silviculture	4	5	12	–	2	2	2	1	2	9
Animal nutrition/pasture & fodder	13	4	3	–	2	4	5	–	6	8
Animal prod. & management	30	28	18	6	11	6	21	10	21	11
Soils/water/ climate/irrigation	4	1	6	1	7	4	2	3	14	4
Plant & animal health and protection	2	1	4	1	4	1	-	2	14	–
Agronomy, plant-breeding	7	1	11	–	–	3	12	10	4	3
Crop & livestock improvement	—	4	4	1	3	–	2	2	4	3
Natural resources	1	1	12	1	1	–	1	–	3	1
Socioeconomic & related themes	4	2	2	3	8	4	2	5	13	8
Others	6	4	10	1	2	1	1	1	3	7
Information not available	12	6	7	–	–	1	6	–	6	2
Totals	193	161	158	34	64	48	91	66	126	166

LIMITING FACTORS AND TECHNOLOGICAL RESTRICTIONS

Table 15 lists 1068 limiting factors and technological restrictions according to the corresponding agroecological zone and area where the institution is located. Table 16 presents the same information classified by type of informant institution. Of the 601 responses that identify the corresponding agroecological zone, almost two-thirds fall into the hot tropics category. Half of all of these were identified by the NARIs.

Nine hundred and fifty-one references were mentioned in relation to limiting factors by species (Tables 17 and 18). Cereals are affirmed as a priority in all areas and types of institutions, except in natural resource and semiprivate institutions and universities. This trend is reinforced when restrictions concerning legumes are added. Fruit restrictions mentioned by universities and semiprivate institutions (when the musaceae are incorporated) and the NARIs in the Southern areas also stand out.[5] Other problematic

Table 15. Limiting factors and technological restrictions by agroecological zone and location of institution

	Subregion of informant institution				Totals	
Agroecological zones	**Central**	**Caribbean**	**Andean**	**Southern**	**N**	**%**
Warm-arid, semiarid tropics	54	28	18	39	139	23
Warm, subhumid tropics	45	21	31	24	121	20
Warm humid tropics	62	17	52	1	132	22
Cool tropics	16	—	9	—	25	4
Semiarid subtropics (summer rainfall)	3	—	3	20	26	4
Subhumid subtropics (summer rainfall)	3	—	6	19	28	5
Cold-humid subtropics (summer rainfall)	34	—	8	28	70	12
Cold subtropics (summer rainfall)	11	—	23	8	42	7
Cold subtropics (winter rainfall)	—	—	3	15	18	3
Some	47	15	5	33	100	100
All	—	2	6	—	8	—
No indication	48	24	137	150	359	—
Totals N	323	107	301	337	1068	—
%	30	10	28	32	—	—

5 Fruit-related problems are divided into temperate and tropical zone problems.

Table 16. Limiting factors and technical restrictions by agroecological zone and kind of institution responding.

Agroecological zones	Type of informant institution					Totals	
	NARIs/ cent. res. progs.	Of. nat. res. inst	Other pub. inst.	Univ./ semip. inst.	Reg. int'l ctrs.	N	%
Warm-arid, semiarid tropics	31	7	69	15	17	139	23
Warm, subhumid tropics	34	2	54	6	25	121	20
Warm humid tropics	75	13	10	6	28	132	22
Cool tropics	17	—	—	—	8	25	4
Semiarid subtropics (summer rainfall)	14	—	9	—	3	26	4
Subhumid subtropics (summer rainfall)	12	—	10	—	6	28	5
Cold-humid subtropics (summer rainfall)	38	—	21	3	8	70	12
Cold subtropics (summer rainfall)	23	2	8	3	6	42	7
Cold subtropics (winter rainfall)	18	—	—	—	—	18	3
Some	36	4	40	7	13	100	100
All	6	—	—	—	2	8	—
No indication	230	8	53	52	16	359	—
Totals N	534	36	274	92	132	1068	—
%	50	3	26	9	12	—	100

Table 17. Technological restrictions and limiting factors by species and location of responding institution.

Species	Subregion of informant institution				Totals	
	Central	Caribbean	Andean	Southern	N	%
Oilseeds	14	2	22	25	63	7
Vegetables	35	10	9	23	77	8
Fruits	36	6	12	43	97	10
Musaceae	5	21	3	2	31	3
Cereals	52	24	47	54	177	19
Legumes	18	7	36	14	75	8
Roots and tubers	19	9	34	5	67	7
Pasture and fodder	15	—	19	17	51	5
Coffee-cacao-tea-herbs-maté	49	4	4	6	63	7
Other vegetables	24	2	11	12	49	5
Forest-agroforest	15	8	15	24	62	6
Other animals (not specified)						
Cattle	5	2	14	15	36	4
Sheep-goats-pigs-camelidae	12	5	9	21	47	5
Crops (not specified)	16	1	11	8	36	4
	2	4	1	13	20	2
Totals N	317	105	247	282	951	—
%	33	11	26	30	—	100

categories include vegetables and roots and tubers. Taken together, these indications seem to reflect a growing problem caused by diversification of agriculture into fruits and vegetables, new opportunities in international markets, and internal urbanization and industrialization.

By theme (Tables 19 and 20), the most frequent restriction concerns health and sanitation (including problems with pests, diseases, and biological control and integrated pest management); production technology and management; livestock and crop improvement; and the soil-water complex. In general, few mentions were made of new fields such as biotechnology or production sustainability, except under soil and water themes.

Table 18. Limiting factors and technological restrictions according to species and type of responding institution.

Species		Type of informant institution					Totals	
		NARIs/ cent. res. progs.	Of. nat. res. inst	Other pub. inst.	Univ./ semip. inst.	Reg. int'l ctrs.	N	%
Oilseeds		43	—	6	6	8	63	7
Vegetables		57	—	7	7	6	77	8
Fruits		67	—	16	8	6	97	10
Musaceae		4	—	10	16	1	31	3
Cereals		94	1	52	7	23	177	19
Legumes		16	1	17	5	36	75	8
Roots and tubers		43	—	4	1	19	67	7
Pasture and fodder		10	—	22	2	17	51	5
Coffee-cacao-tea-herbs-mate		12	—	48	2	1	63	7
Other vegetable		26	3	14	4	2	49	5
Forest-agroforest		10	31	14	7	—	62	6
Other animals (not specified)		22	—	11	1	2	36	4
Cattle		25	—	15	7	—	47	5
Sheep-goats-pigs-camelidae		32	—	3	—	1	36	4
Crops (not specified)		7	—	7	5	1	20	2
Totals	**N**	468	36	246	78	123	951	—
	%	49	4	26	8	13	—	100

Table 19. Limiting factors and technological restrictions by theme and area of responding institution.

Themes	Area of informant institution				Totals	
	Central	Caribbean	Andean	Southern	N	%
Crop & livestock improvement	48	11	31	66	158	15
Prod. tech. & management	56	14	38	68	176	16
Harvest/post-harv/market/agroindustry	22	12	13	11	58	5
Seeds/propagation/germ plasm	16	8	16	12	52	5
Soil (Fertilizer/degradation/condition)	25	13	29	29	96	9
Water (irrig/absorb/ contamination)	20	11	20	20	71	7
Health (pests/disease/bio. control/IPM)	67	20	60	42	189	18
Weeds	19	2	4	17	42	4
Climate/wind/seasonal variation	7	5	20	18	50	5
Others	8	3	24	13	48	4
Econ./soc./cultural problems	15	4	11	13	43	4
Conditions for research	4	—	6	—	10	1
Production quality	3	1	3	9	16	1
Yield/productivity/cost	16	4	23	19	62	6
Totals N	326	108	298	337	1069	—
%	30	10	26	32	—	100

Table 20. Limiting factors and technological restrictions by theme and type of responding institution.

Themes	Type of informant institution					Totals	
	NARIs/ cent. res. progs.	Of. nat. res. inst	Other pub. inst.	Univ./ semip. inst.	Reg. int'l ctrs.	N	%
Crop & livestock improvement	73	1	60	9	13	156	15
Prod. tech. & management	90	4	59	11	12	176	16
Harvest/post-harv/market/ agroindustry	32	2	6	8	10	58	5
Seeds/propagation/germ plasm	24	1	11	9	7	52	5
Soil (Fertilizer/degradation/ condition)	46	4	24	7	15	96	9
Water (irrig/absorb/contamina-tion)	34	4	15	8	10	71	7
Health (pests/disease/bio. control/IPM)	93	5	41	21	29	189	18
Weeds	24	—	14	2	2	42	4
Climate/wind/seasonal variation	24	2	13	2	9	50	5
Others	23	5	10	5	5	48	4
Econ./soc./cultural problems	21	2	10	4	6	43	4
Conditions for research	3	5	—	2	—	10	1
Production quality	10	—	3	—	3	16	1
Yield/productivity/cost	36	1	11	4	10	67	6
Totals N	533	36	277	92	131	1089	—
%	50	3	26	9	12	—	100

HUMAN RESOURCES AND CITATIONS OF NATIONAL TECHNICAL WORKS ON PRIORITY SETTING

The institutions supplied 467 names of people designated as competent to carry out research on priority setting (Table 21). Out of this number, 38% were proposed by Central American institutions and another 31% by Southern Cone country institutions. Likewise, 62% of the proposed experts have a doctorate or master's degree. Finally, a smaller group of institutions identified 232 bibliographical citations of works on priority setting in agricultural or forestry research.

These results suggest the existence of considerable capacity and experience in LAC for addressing priority setting issues.

Table 21. Experts on setting priorities by location according to type of responding institution.

	Technicians in priority areas									
	Subregions									
Type of Institution	Central		Caribbean		Andean		Southern		Totals	
	1	2	1	2	1	2	1	2	1	2
NARIs/central research centers	60	34	13	—	31	30	40	26	144	90
Official natural resource institutions	29	5	9	2	16	5	10	5	64	17
Other public institutions	40	23	13	10	11	—	94	75	158	108
Universities and semipriv. inst.	50	35	22	16	15	11	—	87	62	—
Regional and int'l. centers	—	—	7	6	7	7	—	—	14	13
Totals	179	97	64	34	80	53	144	106	467	290

Note: (1) = totals, (2) those with master's or doctoral degrees. Some people were mentioned by various institutions.

Table 22. Citations of works and publications on priority setting and institutions involved, by their type and location.

	Subregion				
Type of institution	Central Citations	Caribbean Citations	Andean Citations	Southern Citations	Total Citations
NARIs/Central research centers	9	6	9	59	83
Official natural resource institutions	14	4	4	—	22
Other public institutions	9	8	5	38	63
Universities and semipriv. instits.	7	16	41	—	64
Regional and int'l. centers	—	2	1	—	3
Totals	39	36	60	97	235

CONSIDERATIONS CONCERNING EVOLUTION

An important question raised by this inventory concerns the degree of evolution of research capacities in LAC. It is addressed here by way of two main indicators: the number of researchers and research expenditures. The best source for this information is the data compiled and systematized by the International Service for National Agricultural Research (ISNAR) up through the mid-1980s (for example, Pardey and Roseboom 1989; Pardey, Roseboom, and Anderson 1991).

Before attempting to make comparisons, however, it is important to consider the difficulties and dangers presented by the differences in concept and coverage. The ISNAR data do not cover the natural resource agencies, in particular the forestry agencies, which have been partially covered in this work. Regional and international centers are not covered either (CIAT, CIP, CATIE, CIMMYT). In sum, with a few exceptions, the ISNAR information is limited to the NARIs. Table 24 presents the coverage details for the main countries, taken from Pardey and Roseboom (1989). Finally, the ISNAR coverage in the Caribbean is broader than ours in some countries. Also, the adjustments made for exchange rate to standardize costs were different and more complex in the ISNAR data than those employed in this inventory.

Taking all these considerations into account, Pardey, Roseboom, and Anderson (1991:249) estimate a total of 9000 researchers and US$709 million (in 1980 dollars) in research expenditures in LAC for the 1981-85 period. If this amount is translated into 1992 dollars,[6] the total sum ascends to US$1,174,800,000.

The contrast with the adjusted results of the inventory—10,500 researchers and US$709 million[7] in expenditures—paints a dramatic picture. In effect, while the number of researchers rose almost 17% during the period, total expenditures dropped by almost two-thirds (65.7%).[8]

This conclusion, however, is premature inasmuch as the data obscure serious problems in comparability in at least three substantial aspects. The first concerns the dollar conversion method employed by ISNAR. The second refers to the inventory's institutional coverage in the Caribbean area. And third, comparability problems arise from coverage differences between ISNAR and the inventory.

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6 The total number of programmatic areas is 801, but in 14 cases the information is incomplete for some variables; therefore, some tables show results for the remaining 787. The same occurs regarding the 6877 researchers, which are reduced to 6693 in some tables.

7 The adjustments for the Caribbean area for the INIFAP and the CIMMYT discussed in previous sections are included.

8 v.g. (10,500 -9000) x 100/9000 and (1174.8 - 709) x 100/709. The basis for the percentage is always of a lesser magnitude.

In relation to the first point, the ISNAR 1988 dollars are expressed in terms of "purchasing power parity" (PPP). This means that the adjustments have been made using a relative cost comparison in local currencies of a tradable and nontradable goods and services basket (Crain et al. 1991:134) as a reference. Although the transformation does offer some conceptual and methodological advantages for comparison (see previously cited source and also Pardey and Roseboom 1989:23-35), it does not allow for direct comparisons with results based on conventional exchange rates. In effect, the estimated magnitude in dollars expressed in terms of PPP in LAC exceeds the estimates made using conventional exchange rates by 50%.

The ISNAR data taken for the comparison come from Pardey, Roseboom, and Anderson (1991:417-418), which in turn is based on data from Pardey and Roseboom (1989) with some adjustments. On the country level, this last source presents expense values expressed not just in PPP dollars, but exchange rates based on the World Bank Atlas as well. Although the Pardey, Roseboom, and Anderson (1991) data only appear in PPP dollars, they did generate estimates equivalent to the Atlas dollar (using Pardey and Roseboom 1989), which allows for greater comparability with inventory data in cases where the FMI exchange rates were used.

In addition, in the Caribbean, only the data from the countries for which there is inventory information have been retained. The results appear in Table 23. The yield is a total of PPP$682 million (1980), equivalent to US$4.8 billion (Atlas) for the same year.[9] The latter figure was in turn converted to 1992 dollars, which yielded a total of US$664 million[10] in comparison to the US$705 million for 1992 obtained by the inventory —adjusted for Mexico and the CIMMYT according to the sources indicated in the section on budget and financing.[11] In sum, an increase of US$41.4 million in 1992 dollars appears between the two periods. The increase in researchers is slightly less evident when the values for those countries not covered in the inventory are reduced from the ISNAR data.

Although this improves the comparability in dollars, serious problems remain due to the difference in institutional coverage between ISNAR and the inventory and the limitations already mentioned concerning the treatment of the Caribbean. As was noted previously, ISNAR coverage was essentially limited to the NARIs. Based on the notes of Pardey and Roseboom (1989), summarized in Table 24, the ISNAR national data on researchers and expenditures for 1981-85 have been adjusted to limit them to the NARIs in South and Central America.[12] The same was done with the inventory data, but Chile and Costa Rica were eliminated due to difficulties in comparability for the two periods.

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9 Pardey, Roseboom, and Anderson (1991) estimate a total of PPP$708.8 million in research spending in LAC. Table 23 only includes Caribbean countries covered by the inventory and for which data were reported.

10 This was arrived at using the implied deflator of the GDP of the United States, according to the IMF, which yielded a multiplying correction factor of 1657 between 1980 and 1992.

11 Which is to say, US$83.6 million in 1992 dollars are added for INIFAP based on the US$75 million for 1991 reported in Alarcón and Elías Calle (1992:6) and US$33.7 million reported as spending in 1992 by the CIMMYT (1993:17).

12 With the exception of Chile, for which we could not identify a criterion for estimating the NARI component separate from the universities component, which were also included in the ISNAR data. We also exclude Nicaragua, which did not have a research institute at the time when the inventory's information was collected.

The results presented in Table 25 are impressive. The majority of the NARIs —10 out of 14— present a combination of increase in number of researchers and a parallel drop in real expenditures.

Overall, the group of NARIs studied present a 15% decrease in expenditures, combined with a 22% increase in number of researchers, which leads to a drop in expenditures per capita for these of more than 40%. The trend occurs in the three geographic areas, descending in seriousness from Central America (including Mexico), to the Andean, and then Southern areas.

It is clear that this weakening of the NARIs is main source of the crisis in innovation systems and agricultural research in LAC. The NARIs still account for two-thirds of the expenditures and have an even greater proportion of the researchers identified by the inventory at their disposal. Although more exhaustive coverage of other kinds of institutions—universities and businesses, for example—would reduce the prior estimate of the NARIs' participation, they would beyond a doubt constitute a key subsector in the national agricultural innovation systems. Therefore, the crisis in that subsector is transmitted to, and reverberates in, the viability and functioning of said systems. No strategy or policy directed toward strengthening agricultural innovation in LAC should ignore this problem.

Table 23. Research expenditures (1981-85 and 1992) by country and location.

	1981-85 data		1992 data	
	PPP	ATLAS	ATLAS	Inventory
	In millions of 1980 US dollars		In millions of 1992 US dollars	
Argentina	61.7	28.2	46.7	103.5
Brazil	292.3	192. 6	319.1	279.4
Chile	26.9	13.7	22.7	6.7
Paraguay	10.2	7.1	11.8	1.1
Uruguay	4.1	2.6	4.3	12.6
Southern Cone subtotals	395.2	244. 2	404.6	403.3
Bolivia	2.3	0.8	1.3	5.2
Colombia	47.9	23.0	38.1	50.2
Ecuador	13.3	7.2	11.9	4.5
Peru	20.3	8.3	13.8	36.7
Venezuela	35.9	27.0	44.7	21.4
Andean subtotals	119.7	66.3	109.8	118.0

Table 23. (Cont.)

	1981-85 data PPP	 ATLAS	1992 data ATLAS	 Inventory
	In millions of 1980 US dollars		In millions of 1992 US dollars	
Costa Rica	2.8	1.9	3.1	38.9
El Salvador	5.4	2.7	4.5	6.3
Guatemala	7.3	4.1	6.8	7.1
Honduras	2.6	1.6	2.6	1.7
Mexico	129.0	69.0	114.3	(117.3)
Nicaragua	5.1	1.8	3.0	3.9
Panama	6.1	4.2	7.0	5.7
Central Area subtotals	158.3	85.3	141.3	180.9
Antigua and Barbuda	0.2	0.1	0.2	0.3
Barbados	1.8	1.3	2.1	0.7
Belize	0.7	0.4	0.6	0.3
Dominica	0.2	0.1	0.2	0.5
Haiti	1.7	0.6	1.0	0.8
Dominican Republic	4.0	2.4	4.0	0.3
Saint Vincent and the Grenadines	0.2	0.1	0.2	0.3
Caribbean subtotals	8.8	5.0	8.3	3.2
Totals in LAC	682.0	400.8	664.0	705.4

Table 24. ISNAR data coverage for the period 1981-85.

Argentina	Personnel and expenditures only for the National Agriculture Institute (INTA). Expenditures correspond only to research and were obtained as an estimate (68%) of the total for 1984-86.
Brazil	Covers federal and national expenditures for EMBRAPA, state institutions, and integrated program and special programs. EMBRAPA represented 78% of expenditures in 1981 and 42.4% of researchers in 1981-85.
Bolivia	Personnel and expenditures only correspond to the Bolivian Agricultural Technology Institute (IBTA).
Chile	Personnel and expenditures correspond to the NARI and the four agriculture units of the four universities. Data on personnel proportions not provided.
Colombia	Personnel and expenditures for the period correspond to the ICA and CENICAFE. The personnel average for ICA was 403 and expenditures 52.28%.
Costa Rica	Personnel and expenditures only correspond to the Ministry of Agriculture (MAG).
Ecuador	Personnel and expenditures only refer to the National Agricultural Research Institute (INIAP).

Table 24. (Cont.)

El Salvador	Both values appear to correspond to the CENTA and Salvadoran Coffee Research Institute (ISIC) only. In 1980, CENTA's percentage participation was 69.8% in personnel and 67.4% in budget.
Guatemala	Both values correspond only to the Science and Agricultural Technology Institute (ICTA).
Mexico	Only for the NARI.
Nicaragua	Data for the General Directorate of Agricultural Technology (DGTA) in 1984, General Agricultural Directorate (DGA) only.
Panama	Only the Center for Agricultural Research (IDIAP).
Paraguay	Only the Directorate for Agricultural and Forestry Investigation and Extension (DIEAF)
Peru	The National Agricultural Research and Promotion Institute (INIPA).
Uruguay	Only the Alberto Borges Agricultural Research Center
Venezuela	Only the National Agricultural Research Fund (FONAIAP).

Table 25. Comparison of researchers and expenditures for NARIs in the periods 1981-85 and 1992-93 (in millions of 1992 US$).

Country	NARIs for 1981-85		NARIs for 1992-93	
	Researchers	Expenditures	Researchers	Expenditures
Argentina	1062	46.7	46.7	70.4
Brazil	1610	248.9	248.9	217.3
Paraguay	86	11.8	11.8	1.6
Uruguay	77	4.3	4.3	12.6
Subtotals	2835	311.7	311.7	301.7
Bolivia	104	1.3	1.3	5.0
Colombia	402	19.9	19.9	18.8
Ecuador	211	11.9	11.9	4.3
Peru	262	13.8	13.8	22.7
Venezuela	383	44.7	44.7	20.6
Subtotals	1363	91.6	91.6	71.4
El Salvador	75	4.5	4.5	.8
Guatemala	160	6.8	6.8	4.3
Honduras	65	2.6	2.6	.5
Mexico	1058	114.3	114.3	83.6
Panama	115	7.0	7.0	5.4
Subtotals	1473	135.2	135.2	94.6
Totals	5671	538.5	538.5	467.9

* In this case we used the reported figure for personnel with a university degree or greater who work in research; the figure of 1315 researchers with this education level includes personnel who carry out other functions.

APPENDIX 1

Number of Personnel and Researchers in the Research Institutions by Country

Country	1	2	3	4	5	6	7
Costa Rica	2,826	369	369	104	74	38,949.2	40,227.4
Nicaragua	1,916	279	233	33	4	3,931.6	3,931.6
Guatemala	2,418	333	288	47	5	6,300.6	6,320.6
Honduras	555	286	188	37	37	1,688.5	3,307.0
Panama	1,508	188	178	75	19	5,643.5	5,007.7
El Salvador	1,356	83	52	10	2	7,095.4	7,095.4
Barbados	21	7	7	3	1	718.3	661.4
Haiti	204	35	35	16	3	799.7	819.7
Trinidad and Tobago	65	6	6	5	1	7.8	—
Guyana	154	6	2	—	1	—	—
Saint Vincent and the Grenadines	50	7	7	4	—	333.0	333.0
Belize	233	12	7	6	—	310.7	310.7
Dominica	45	10	10	5	1	460.8	95.5
Antigua and Barbuda	5	5	5	4	1	258.4	225.8
Dominican Republic	43	30	11	4	333.2	333.2	
Colombia	2,769	1,385	880	243	166	56,184.7	50,186.9
Venezuela	3,204	1,027	538	239	27	21,371.5	28,660.6
Ecuador	1,015	255	255	65	1	4,482.6	4,482.6
Peru	1,318	578	271	36	42	36,718.5	36,718.5
Bolivia	805	141	123	17	3	5,221.6	5,723.2
Argentina	1,375	1,015	1,015	249	72	103,531.8	103,531.8
Brazil	19,960	4,045	3,504	1,910	848	279,390.1	311,280.8
Chile	1,250	262	261	81	30	6,731.1	6,731.1
Paraguay	276	221	132	35	—	1,059.6	2,111.8
Uruguay	483	149	126	46	5	12,585.2	12,585.2
Totals	43,854	10,734	8,522	3,281	3,281	588,107.6	620,680.8

1 = total personnel
2 = personnel in research
3 = researchers
4 = researchers with a master's
5 = researchers with a doctorate
6 = researchers in NARIs
7 = researchers in official natural resource institutions
8 = researchers in other public institutions
9 = researchers in universities and semiprivate institutions
10 = researchers in regional and international centers

APPENDIX 2

Research Institutional Expenditures in 1992 by Type and Country Where Located (in US$)

Country	NARIs/ cent. res. progs.	Of nat. res. insts.	Other pub. insts.	Univ./ semipr. insts.	Reg./int'l. centers	Total
Costa Rica	15,519,487	0	923,653	3,676,440	18,829,440	38,949,202
Nicaragua	0	350,718	1,549,838	820,310,000	0	3,931,556
Guatemala	4,265,633	0	2,035,003	0	0	6,300,636
Honduras	526,525	87,479	0	1,064,494	0	1,688,498
Panama	5,360,838	176,676	0	106,000	0	5,643,514
El Salvador	774,086	25,775	1,001,319	5,294,267	0	7,095,447
Barbados	0	0	0	0	718,309	718,309
Haiti	0	71,600	668,144	60,000	0	799,744
Trinidad and Tobago	0	0	0	0	0	0
Guyana	0	7,811	0	0	0	7,811
Saint Vincent and the Grenadines	178,148	0	0	0	154,815	332,963
Belize	130,737	0	0	0	179,983	310,720
Dominica	0	0	0	0	460,781	460,781
Antigua and Barbuda	0	0	0	0	258,413	258,413
Dominican Republic	321,742	0	0	11,500	0	333,242
Colombia	18,793,067	391,675	0	0	31,000,000	50,184,742
Venezuela	20,619,808	334,913	0	416,813	0	21,371,534
Ecuador	4,276,884	205,672	0	0	0	4,482,556
Peru	22,654,476	0	0	0	14,064,000	36,718,476
Bolivia	4,988,282	225,641	7,718	0	0	5,221,641
Argentina	103,531,786	0	0	0	0	103,531,786
Brazil	217,286,872	0	62,103,300	0	0	279,390,172
Chile	5,770,338	960,786	0	0	0	6,731,124
Paraguay	520,000	0	539,563	0	0	1,059,563
Uruguay	12,585,172	0	0	0	0	12,585,172
Total	438,113,881	2,838,746	68,828,538	12,660,696	65,665,741	588,107,602

APPENDIX 3

Research Institution Income in 1992 by Type and Country Where Located (in US$)

Country	NARIs/ cent. res. progs.	Of nat. res. insts.	Other pub. insts.	Univ./ semipr. insts.	Reg./int'l. centers	Total
Costa Rica	15,941,496	15,941,496	985,524	3,750,970	19,549,440	40,227,430
Nicaragua	0	0	1,549,869	2,031,000	0	3,931,556
Guatemala	4,265,633	4,265,633	2,054,342	0	0	6,319,975
Honduras	526,525	526,525	0	2,683,019	0	3,307,023
Panama	4,832,000	4,832,000	0	0	0	5,007,680
El Salvador	774,086	774,086	1,001,318	5,294,267	0	7,095,446
Barbados	0	0	0	0	661,426	661,426
Haiti	0	0	668,144	80,000	0	819,744
Trinidad and Tobago	0	0	0	0	0	0
Guyana	0	0	0	0	0	0
Saint Vincent and the Grenadines	178,148	178,148	0	0	154,815	332,963
Belize	130,712	130,712	0	0	179,983	310,695
Dominica	0	0	0	0	95,478	95,478
Antigua and Barbuda	0	0	0	0	225,766	225,766
Dominican Republic	321,743	321,743	0	11,500	0	333,243
Colombia	18,793,067	18,793,067	0	0	31,000,000	50,186,917
Venezuela	27,908,915	27,908,915	0	416,813	0	28,660,641
Ecuador	4,276,884	4,276,884	0	0	0	4,482,556
Peru	22,654,476	22,654,476	0	0	14,064,000	36,718,476
Bolivia	4,988,282	4,988,282	509,231	0	0	5,223,154
Argentina	103,531,786	103,531,786	0	0	0	103,531,786
Brazil	250,011,965	250,011,965	62,168,857	0	0	311,280,822
Chile	5,770,338	5,770,338	0	0	0	6,731,124
Paraguay	1,572,157	1,572,157	539,563	0	0	2,111,720
Uruguay	12,585,172	12,585,172	0	0	0	12,585,172
Total	479,073,385	479,073,385	68,576,848	14,267,569	65,930,908	630,680,824

APPENDIX 4

Number of Researchers by Type of Institution and Country

Country	Type of Institution				
	NARIs/ cent. res. progs.	Of nat. res. insts.	Other pub. insts.	Univ./ semipr. insts.	Reg./int'l. centers
Costa Rica	66	—	41	81	182
Nicaragua	—	16	61	156	—
Guatemala	164	—	25	—	—
Honduras	62	20	—	106	—
Panama	124	17	—	55	—
El Salvador	99	13	25	14	—
Barbados	—	—	—	—	7
Haiti	—	2	38	1	—
Trinidad and Tobago	—	—	—	—	10
Guyana	—	2	—	—	—
Saint Vincent and the Grenadines	6	—	—	—	3
Belize	5	—	—	—	2
Dominica	—	—	—	—	10
Antigua and Barbuda	—	—	—	—	5
Dominican Republic	13	—	—	26	—
Colombia	422	23	—	—	435
Venezuela	504	17	—	17	—
Ecuador	238	17	—	—	—
Peru	153	—	—	—	118
Bolivia	115	7	1	—	—
Argentina	1,315	—	1,416	—	—
Brazil	2,088	—	—	—	—
Chile	189	72	20	—	—
Paraguay	112	—	—	—	—
Uruguay	126	—	—	—	—

APPENDIX 5

Institutional Inventory of Regional Priorities for Agricultural and Forestry Research (AFR) in Latin America and the Caribbean

CHAPTER I: INSTITUTIONAL REFERENCES[1]

1. Name of the institution

____

____

2. Full address

____

____

3. Telephone ____________ 4. Fax ____________ 5. Telex ____________

6. Person responsible for providing the information:

6.1 Name ____________ 6.2 Position ____________

CHAPTER II: RESOURCES AND AREAS OF WORK[2]

1. Personnel:

1.1 Total number of personnel ____________
1.2 Involved in research[3] ____________
1.3 Researchers commissioned to carry out studies[4] ____________

2. Number of researchers according to their highest qualification:

2.1 University degree[5] ____________
2.2 Master's degree ____________
2.3 Ph.D ____________

1 Attach a recent organizational chart for the institution.
2 Information on personnel as of December 1992.
3 Personnel who execute and/or direct research.
4 Commission abroad or within the country for over six months.
5 B.Sc. or equivalent.

3. Distribution of the number[6] of full-time or equivalent researchers by type[7] of research:

   1. Basic research (pure and strat.) ____________________
   2. Applied research and tech. gen. ____________________
   3. Adaptive research ____________________

4. **Total approved** budget in local currency for research in 1992 by object of expenditure[8]:

   1. salaries and wages ________________
   2. operating exp.[9] ________________
   3. investment ________________
   4. total ________________

5. Sources of total approved income (4.4 above)[10]

   1. government/fiscal budget ____________________________
   2. own resources ____________________________
   3. external resources ____________________________
   4. other (specify) ____________________________

6. Number of different species for which at least one research experiment was carried out in 1992.

   1. annual crops ________ 4. pasture and forage ________
   2. perennial crops ________ 5. terrestrial animal species ________
   3. tree species ________ 6. aquatic animal species ________

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6 Or the best possible percentage estimate if there is no information on absolute values.

7 The objective of basic, pure and strategic research is to generate new concepts and basic knowledge (theory, methods and findings). In most cases these are not immediately applicable to practical problems, although eventually they may be.
The purpose of applied research and technology generation is to develop new expertise or technologies that are directly applicable to the solution of a practical (technical) problem. In agriculture these results are initially valid for a specific recommendation domain but can be extended (through adaptive research) to other domains and conditions.
The aim of adaptive research is to extend existing knowledge or technologies to different domains and conditions. This is done through incremental testing, validation and adjustment or modification.

8 Including the proportional part of general administration and other expenses shared with activities other than research.

9 Expenses for conducting research that does not include salaries, wages or investment.

10 Internal resources: sale of products, services and technology. External resources: external credits and donations.

CHAPTER III: CENTERS AND STATIONS

Name of Center or Exp. Station[11]	Number of Researchers[12]	Agroecological zone[13]	Main commodities and/or areas of work

11 Exclude experimental farms or fields.
12 Full-time or equivalent and with at least one university degree.
13 Refer to the appendix containing classifications.

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Chapter 2

AGROECOLOGICAL DIMENSIONS OF EVALUATING AND PRIORITIZING RESEARCH FROM A REGIONAL PERSPECTIVE: LATIN AMERICA AND THE CARIBBEAN*

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CONTENTS

FOREWORD

This ISNAR report has been prepared as a contribution to a IDB/IICA initiative to explore the need for, and feasibility of, enhanced support in quantitative research evaluation in Latin America and the Caribbean (LAC). The report, which focuses primarily on the scope for improved integration of environmental factors in evaluation methodologies, is based upon a 21-day period of investigation spent mostly in the LAC region, but including short visits to ISNAR, The Hague, and FAO (Rome) to collect additional material. Given the limitations of this input and the size and complexity of the LAC region, the report cannot hope to be comprehensive in its coverage. However, it attempts to set out in broad terms some of the essential considerations and potential problems associated with the proposed analysis at the regional scale, and provides illustrative examples of the ways in which the environmental component of such analyses might be performed.

Specific Issues addressed are (a) the role of agroecology in the research evaluation process, (b) the availability of data to support research evaluation analyses at the regional and national level, (c) the extent to which agroecological or agroecosystem zoning is currently used in the region, and (d) the identification of cases where significant regional benefits have been realized as a consequence of agroecosystem-targeted research.

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INTRODUCTION

Agricultural research can be viewed as a means of increasing the social returns to agricultural production activities within windows of opportunity presented by a natural environment that varies in both time and space. Within these windows, the choice of the agricultural production system is dominated by the nature of markets for agricultural inputs and outputs and by considerations of infrastructure, demography, and culture. While it is true that some extremely capital-intensive production systems can create their own artificial environments (e.g., glasshouse production of high-value horticultural products), these are of marginal importance in the vast majority of developing countries. The quality of land, the quantity and timing of radiation and water resources, and the effects of natural hazards such as frost, flood, and typhoon remain, as farmers worldwide will testify, the most fundamental of the binding constraints to agricultural production. Agricultural research seeks both to improve the productivity of agricultural inputs within these boundaries and, often with great success, to shift the constraining boundaries by altering the abiotic (environmental) adaptability ranges of plants and animals, or by limiting the impact of biotic (pest and disease) constraints that are themselves often confined to specific environmental domains. Increasingly, agricultural research is also called upon to address issues arising from the external consequences of agricultural production, in particular to develop technologies that minimize environmental degradation.

Clearly the efficient allocation of scarce research resources across the range of socially important production systems, in a myriad of environmental, sociopolitical and market situations, presents a significant challenge to research policymakers and managers. To help meet this challenge, analysts have developed a range of research evaluation methodologies that attempt to quantify the effects of alternative research investment strategies. These include the assessment of effects arising from both past investments (ex-post analyses) and current or proposed investments (ex-ante analyses). These effects can be variously expressed in terms of subjective scores, physical productivity indicators, or monetary measures of social benefit. Although much of the early work in research evaluation focused on assessing the aggregate effects of research at the commodity level, demands have grown for greater disaggregation to explore the consequences of other strategic resource allocation options. To meet these demands, and to improve our estimates of the aggregate benefits, recent evaluation methods have attempted to partition research activities and their effects by various commodity subtypes, environments, and problem/discipline domains.

This report explores the environmental component of these assessment procedures within the broader technical dimensions of quantified research evaluation and priority setting for LAC. Alston, Norton, and Pardey (1993) provide a comprehensive review of the complementary economic dimensions of evaluating and prioritizing research. Both technical and economic dimensions are necessary, but neither are sufficient. The fundamental challenge, also addressed in this report, is to integrate them in ways that reflect their real-world interdependence.

After briefly defining our usage of agroecological terminology, based, as far as possible, on terminology current in the LAC region, an overview is given of environment-agriculture linkages most relevant to establishing research priorities. The next section of the report deals with some specific methodological issues of integrating agroecological analysis into a quantified, hierarchical framework for research priority setting and resource targeting at regional, national, and subnational levels in LAC–always with special emphasis on improved contributions from the discipline of agroecology to the overall decision support system.

As a more practical input to the proposed IDB/IICA regional initiative, a companion volume provides a preliminary inventory of regional agroecological data available to research analysts in digitized (computer-based) map formats.

AGROECOLOGY TERMINOLOGY

The Latin American region is no exception to the disparate use of terminology to describe environment-agriculture relationships. CIMMYT's wheat *mega-environments*, FAO's *agroecological zones*, and the CGIAR system's *ecoregions* are dictated by purely environmental characteristics. CIAT's *agroecosystem* clusters and the Amazon Treaty's *ecologic-economic* zones represent a more ambitious integration of environment with selected infrastructure and socioeconomic criteria. For the purposes of this report, the following terminology is adopted:

Agroecology is the generic name given to the study of the environment-agriculture interface.

Agroecological zone (AEZ) is used to describe a geographical area that is homogeneous with respect to its environment and natural resources, e.g., climate, land form, soils, and water bodies. Most importantly, for our purposes, an AEZ is also expected to display a broadly uniform *physical* response to the application of agricultural production technologies. Those responses may be in the form of productivity changes or environmental impacts. An important special case of an AEZ is the ***agroclimatic zone*** (ACZ), delineated using only climatic criteria. The CGIAR's ecoregions are agroclimatic zones.

Ecologic-economic zones are the geographical areas described by the superposition on AEZs of additional layers of physical and infrastructural information (e.g., accessibility) and socioeconomic information (e.g., population density, income levels, and land tenure).

Agroecosystems (or production systems) are specific, integrated sets of land use activities that transform a mix of natural resources, capital, labor, purchased inputs, and management skills into economically useful products including food, feed, and fiber.

The underlying principle of this choice of terminology is that an AEZ defines a physically homogeneous area within which a (potentially large) number of *agroecosystems* could be supported. The term AEZ as defined here is widely accepted in the region, from FAO's AEZ study covering Central and South America (FAO 1981) to national examples such as the AEZ maps of Argentina (INTA 1982), Colombia (IGAC/ICA 1985), northeast Brazil (MARA/EMBRAPA undated), and Venezuela (FONAIAP/CENIAP 1982), and the Agroclimatic Zone Map of Chile (INIA 1989) and of the Andes (Frere, Rijks and Rea 1975). The same conceptual basis was used by CIMMYT in defining their wheat *mega-environments* (CIMMYT undated).

The term *ecologic-economic* is adopted because of its current wide use in the region. Several countries, including Brazil, Peru, Venezuela, Guyana, and Ecuador, are planning or executing ecologic-economic zoning at scales from 1:1,000,000 to 1:150,000. Much of this activity is related to the initiative coordinated by the Amazon Cooperative Treaty Secretariat.

The TAC/CGIAR *ecoregions* are currently defined as aggregations of FAO's agroecological (agroclimatic) zones with the addition of administrative boundaries (TAC/CGIAR 1991), but these are implicit in most agroecological data sets. It is likely that these ecoregions will become something akin to ecologic-economic zones as a small number of socio-economic layers, for example population density and market infrastructure, are added to the underlying AEZs.

CIAT's use of terminology cuts across the definitions given above. CIAT's *agroecosystem* programs appear designed to address a number of specific agroecosystem clusters defined in terms of existing land use patterns and identified within a prioritized range of ecologic-economic zones. Thus, although the CIAT program names "Forest Margin," "Hillside," and "Savanna," convey a purely AEZ definition, they are, in reality, based on a structured analysis of ecologic-economic zones and associated agroecosystem clusters (CIAT 1991e).

RESEARCH AND THE ENVIRONMENT: AN OVERVIEW

Clearly agriculture, by its very nature, is inextricably linked to the environment. This section explores the most important components of the environment-agriculture interface and points to opportunities for improved allocation of scarce research resources through the greater integration of environmental considerations into the research decision-making process. Some environment-agriculture interactions, summarized at the macro level in Figure 1, will be identified as strategic in nature and, hence, of major interest in the context of developing a research evaluation framework at the regional and national level in LAC. At this aggregate level, research evaluation can help policymakers and research managers to quantify the potential contribution that alternative investment strategies can make to achieving research goals. Finally, some operational issues will briefly be explored since, if properly formulated, any proposed strategic analytical framework should be capable of conditioning and informing decision making at the operational level.

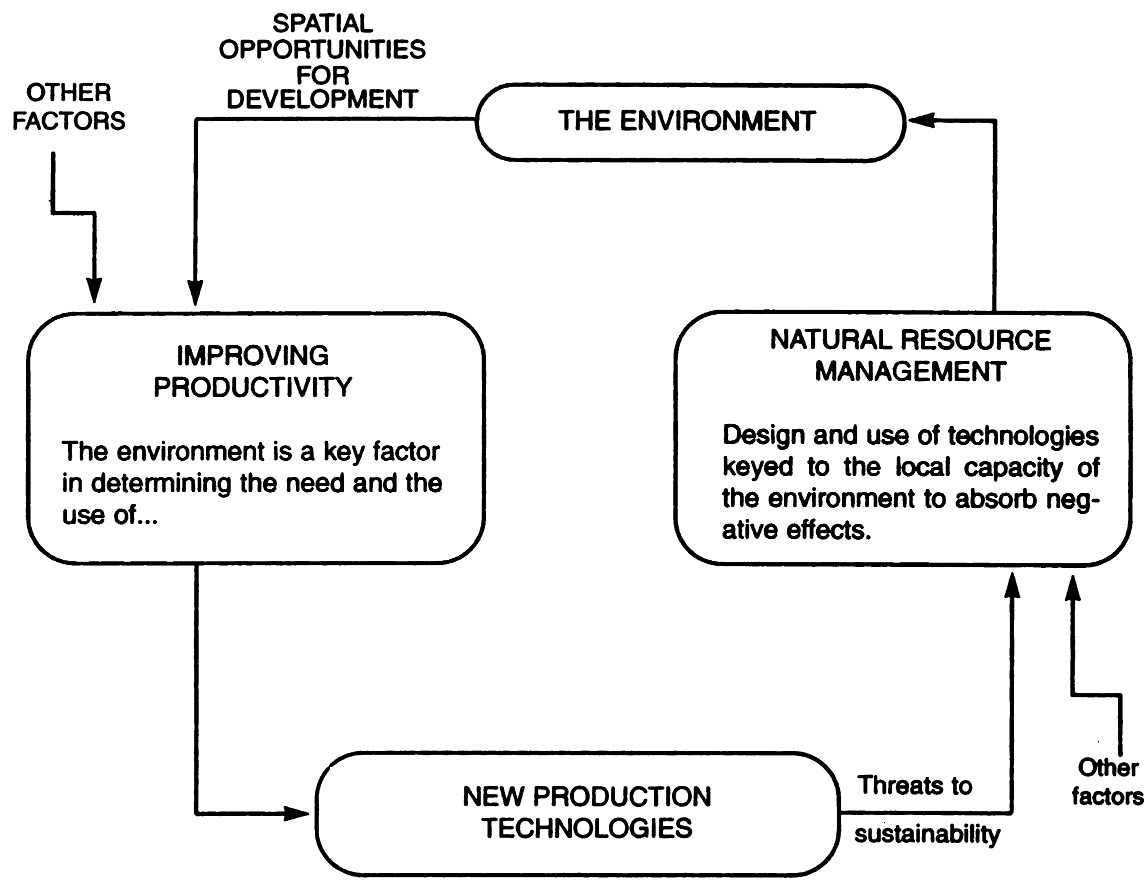

Figure 1. The agricultural research-environment interface: a simplified macro view.

Strategic Research Prioriy Issues

Agricultural research is scientifically complex–and this complexity is further compounded by the need to address a much broader set of goals than scientific excellence alone. Even the traditional growth-oriented goals of increased productivity and improved product quality appear to be no longer adequate. And, almost without exception, today's research managers are called upon to address a range of issues including growth, equity, and sustainability. While economists and others debate whether the technology development sector is the most relevant and effective way of tackling society's equity and sustainability goals (Alston and Pardey 1993), research managers must demonstrate that research programs have been formulated with due regard for these objectives.

The following sections briefly examine some of the ways in which an awareness of agroecology and a related analytical capacity can contribute to attaining the *de facto* research goals of growth, equity, and sustainability.

Growth

Agriculture contributes to growth primarily through improvements in the productivity of land, labor, and capital. Many of the well-established strategies for achieving agricultural growth have strong agroecological dependencies. *Intensification* of production requires careful selection of the most responsive land resources together with the adoption of intensification technologies that minimize the enhanced threat of environmental degradation. *Extensification*, increasingly into less favorable agricultural areas, requires the identification of agroecosystems with the most potential for production expansion while minimizing adverse environmental effects. *Prehabilitation* calls for the identification of viable land improvement options for degraded agricultural land or land that has fallen out of production altogether, often because of excessive environmental degradation associated with previous intensification and extensification efforts.

Examples of the negative environmental effects that can arise from efforts to improve land productivity are not difficult to find in LAC. The declining productivity of the Argentine Pampas is viewed, in part, as a consequence of intensification of grain and legume production without due regard for increased nutrient demands. In tropical areas, there are similar instances of chemical and physical degradation of soils plus damaging changes in the hydrological regime associated with extensification–in this case involving the conversion of forest margins to low-input agricultural production.

However, it is not just in identifying opportunities for, or constraints to, improved land productivity that agroecology can assist in analyzing growth-oriented research options. A significant number of the technologies for improving productivity of labor and other agricultural inputs are also conditioned by agroecological circumstances. Thus, the areas suitable for tractor use are limited by, among other things, slope considerations while manual cultivation technologies are generally ineffective in areas of vertic soil type. There are clearly significant opportunities for and advantages to integrating agroecological considerations into growth-oriented assessments of research effects.

Equity

Equity goals focus attention on the distribution of benefits arising from research-derived technical change. Pursuit of equity goals, often considerably at odds with purely growth objectives, results in the biasing of technology development to bring about some preferred distribution of research benefits. For example, in much of Latin America, where a high proportion of the land is controlled by large-scale landowners, the structure of land ownership gives rise to concerns that technologies appropriate for large-scale operations, while possibly making a big contribution to growth, may have undesirable consequences in terms of benefit distribution. Hence, the "equity pressure" to develop technologies more appropriate to medium- and small-scale operations.

While equity is a sociopolitical issue, it would be wrong to suppose that it is unrelated to agroecology. There is often, but by no means always, a significant relationship between the pattern of income distribution and agroecological factors, usually based on the correlation between land quality and rural income. Marginally productive, inaccessible, often environmentally fragile lands tend to be farmed by poorer farmers who (together with the urban poor) are the most usual target beneficiaries of equity-oriented policies.

Thus, agroecology can contribute to equity-oriented research evaluation in cases where a high correspondence exists between the spatial incidence of specific agroecological conditions, for example steeper slopes, poorer soils, and marginal water availability, and the distribution of disadvantaged social groups. In Ecuador and Peru, for example, there appears to be a significant spatial correspondence between social groupings and various rainforest, sierra, and coastal ecosystems. In such circumstances, partitioning the total benefit from research in a spatial dimension using agroecological criteria can be a useful means of approximating the distributional consequences of agricultural research.

Natural resource management

Within the set of emerging "green issues" or "sustainability concerns," the natural resource management aspects of agricultural production are coming under the increasing attention of policymakers. In this respect, two broad areas of concern generally receive attention: one relates to environmental externalities and the other to resource depletion and intergenerational equity. An externality occurs when one person's actions affect another's economic opportunity, and where that effect is not compensated through a market transaction. For example, agricultural production can cause pollution of ground and surface water with agricultural chemicals or depletion of soil fertility and soil erosion. Another example is the increased instability of the hydrological regime that can follow forest clearing, often to make way for agricultural production. A more abstract example is when such clearing of rainforests also results in species depletion, reduction of pristine wilderness, or other environmental damage which could be regarded as a cost that is not factored into forest management decisions. Agroecological analysis can help to identify those areas where specific agroecosystems are likely to present environmental externality problems (where there may be need for research), and in many cases can also indicate the likely severity of those problems (i.e., the intensity of research). Analyses can also be performed to help identify and evaluate mitigation options (i.e., suggest specific areas of research).

Institutional organization of research

Both national and international research efforts have traditionally been stratified at the highest institutional level by commodity or environment domain.[1] CGIAR research centers such as CIP, IRRI, and CIMMYT are typical of commodity stratification, while CIAT, ICRISAT, and ICARDA have mandates that are stratified by mega-environments.

1 The two domains are not independent-commodity stratification itself implies some measure of environmental stratification, given the finite environmental adaptability range of most plant and animal species and their related pests and diseases.

The relative merits of the primary disaggregation of research by commodity or environment (e.g., agroecological zone) have been the subject of much debate in recent times in the context of CGIAR reorganization (TAC/CGIAR 1991). Increased emphasis on an *ecoregional* zone approach, it is argued, would stimulate research more relevant to the realities of farming, particularly in a developing country context, where highly integrated production of multiple crop and livestock commodities is commonly practiced. Furthermore, it is presumed this approach is more compatible with the growing need to address environmental sustainability concerns. Two examples of commodity program de-emphasis are the strategic restructuring of research within CIAT and PROCISUR. The CIAT restructuring resulted in the emergence of three major "agroecosystem" programs within its broad tropical agriculture mandate, while the ongoing PROCISUR deliberations seem likely to lead to a more sustainability-oriented agricultural research portfolio.

The trend to restructure research activities within an overall agroecological framework, and the (related) increased sociopolitical awareness of natural resource management issues, further indicate that agroecological analysis is an important component of research decision support systems at all levels in the LAC region.

Consequences for Research Investment

We have seen that the formulation of research programs is driven by a set of political and socioeconomic goals and that research evaluation is the process of quantifying the potential contribution of alternative research investments toward those goals. Placing an economic value on the expected effects of research helps in setting research priorities and in guiding the allocation of scarce research resources. It does so by providing a money measure of the effects of research that constitute a common and comparable economic yardstick. This makes it possible to generate summary measures of the expected net social benefits of research that are more readily understood by those funding and executing agricultural research. It also enables research managers to develop research portfolios that target resources to a range of technology developments most likely to maximize beneficial impacts. In this process some basic, strategic questions arise. What are the geographical regions, social groups, and agricultural production systems that should be targeted? What are the relative priorities that should be attached to each of these? What type of technologies would best be developed and how can we assess their likely effects– both technically and economically?

This section explores some of the strategic elements of this decision-making process– with particular emphasis on the role of agroecology. The main discussion addresses individual issues that, because of their interdependence, need to be resolved jointly. They are (a) the targeting of research resources, (b) the expected direct effects of research, and (c) the expected spillover effects of research. Finally, some of the tradeoffs that must be made between these and other research determinants are briefly discussed.

Technology targeting

The research policy environment is typically represented by a set of growth, equity, and sustainability goals, and these in turn give rise to a range of strategic targeting options as summarized in Table 1. Specific *administrative regions* may be important for a range of political and socioeconomic reasons, and these can often be linked to agroecological factors, e.g., agriculturally less-suitable areas that give rise to low rural incomes. However, there is no general and systematic link between regional targeting and agroecology. Targeting *rural social groups* may coincide with a specific set of agroecological conditions, certainly in some parts of LAC, but again, there is no inviolate link between social targeting and agroecology.

Table 1. Strategic targeting options.

Targeting options	Examples
Administrative regions	Areas of political importance, social deprivation, or economic opportunity
Social groups	Landless laborers, small farmers, urban consumers
Agroecological zones	High production potential, environmentally susceptible areas
Production systems	Food crops, mechanized cash crops, extensive livestock
Problems/Technologies	Genetic improvement, pest/disease control, plant/animal husbandry

Targeting *agroecological zones* is commonly practiced. The rationale for doing so is well summarized by Brinkman (1987):

> A universal clone or cultivar would be resistant against a wide range of pests, diseases and other environmental stresses, adapted to a wide range of daylengths, heat and cold tolerant, tolerant to drought and to oxygen deficiency in the root zone (waterlogging), adapted to low fertility but with a large response to fertilizer, and tolerant to a range of toxic conditions in the root zone. Since this ideal cultivar cannot be produced, choices must be made in plant breeding. Cultivars or clones are designed and selected for resistance or tolerance to combinations of stresses prevalent in specific environments.

If zones are properly defined, then new technologies would be expected to have fairly homogeneous effects in terms of both enhanced productivity and environmental consequences within each zone. Agroecological zones may be targeted because of high production potential (i.e., the lack of physical constraints), or because of the existence of specific constraints that research could seek to mitigate, such as acid sulphate soils, pest/disease incidence, and erratic rainfall patterns. Increasingly, the targeting of research is also driven by environmental degradation concerns related to production systems for which remedial or protective technologies may be needed.

Targeting *production systems*, perhaps until recently the most common of targeting strategies, clearly has a high degree of agroecological dependency both in terms of the environmental adaptability ranges of the plant and animal species concerned, and in terms of their associated pests/diseases and environmental degradation effects. Production systems involving more than one market commodity present some analytical challenges that need to be addressed, especially given the movement away from single commodity-oriented research in the LAC region. However, disaggregation of a single market commodity into subcommodities such as ecotypes is also possible. For example, the targeting of research into irrigated, upland, and swamp rice production systems and the very different research impact that can arise from this may be analyzed independently at the agroecology and technology level. This type of limited disaggregation is useful for research evaluation and priority setting even though, for many purposes, reporting the overall market effects for the single commodity rice are sufficient.

The extent to which a strong correspondence exists between the targeting of agroecological zones and production systems/commodities depends on the environmental "plasticity" of the species concerned. Thus, animals tend to be more environmentally adaptable than crops (though some of their pests and diseases may not be), and maize is much more widely adapted than, for example, *arabica* coffee, coconuts, or soybeans. However, it can be said with some certainty that (a) the economic production of a commodity can be found in a finite number of zones, and (b) that different levels of physical production potential (i.e., production suitability) exist between these different zones.[2]

Targeting of specific *production problems* has an agroecological dimension in two important respects. Firstly, research may be designed to address specific agroecological production constraints such as improving tolerance to drought, frost, or acid soils; or environmental degradation problems such as reducing soil erosion or nutrient leaching. Secondly, there is the issue of the *environmental specificity* of research. Environmental specificity reflects the extent to which new technologies are likely to be transferable across agroecological zones. Two polar examples are (a) technologies for improved saline tolerance–which could be considered as totally environment-specific to AEZs having soil with saline phases, and (b) technologies for cloning fruit trees–which, since they are applicable equally to all AEZs in which fruit tree production is feasible, are considered as environmentally nonspecific.

In general, there are several major technology areas to which research may be targeted to address specific production opportunities or constraints, all of which exhibit some level of agroecological dependency:

a. increasing the genetic potential of basic plant and animal materials
b. reducing the impact of abiotic productivity constraints, e.g., improved drought resistance or aluminum tolerance
c. reducing the impact of biotic constraints to productivity–a continuous task, as pest and disease biotypes often develop to erode each technological advance
d. other improved production management techniques, e.g., improved soil/water management

2 Indeed, this is the basis of FAO's AEZ methodology and the general approach taken in most land evaluation analyses.

Ameliorating the effects of abiotic and biotic constraints often has two consequences: it tends to increase productivity of existing production environments, and it also broadens adaptability ranges and, hence, can serve to expand potential production areas. In this sense agricultural research can redefine the spatial and temporal windows of environmental opportunity for agricultural production.

Clearly an important set of resources in the process of targeting research by commodity, zone, research problem, and, to the extent it is possible, by social group, is the availability of appropriate maps and databases describing the spatial pattern and classification of agroecological zones.

Technology impacts

Identifying targeting options and delineating potentially homogeneous zones are some of the initial tasks of the research evaluation analyst. However, if we are to pursue the objective of quantified research evaluation it is also necessary to assess the potential physical and economic effects of research within each zone. The extent to which the potential effects of new technology are realized depends on the extent to which that technology is adopted. For the purposes of this discussion, we focus on impact assessment assuming full adoption–this benchmark, "potential" impact can be modified later to take account of expected spatial variation in adoption. Clearly, however, it must always be unambiguous whether zones are defined purely by physical characterization, as in FAO's AEZs, or whether they include other criteria such as ecologic-economic zoning. AEZs can only be used to assess *potential* physical impact, whereas ecologic-economic zones may include sufficient factors to delineate zones having uniform economic effects and, hence, could provide a basis to assess *realized* effects directly.

The analytical procedures to convert the physical effects of new technology into measures of economic benefit usually require these effects to be expressed ultimately as a reduction in the unit cost of production. However, the range of direct measures of technology impact is wide, including the following:

a. Yield increase (e.g., kg/ha)
b. Factor increase or decrease (e.g., $/kg of output)
c. Product quality (price) increase (e.g., $/kg of output)
d. On-site or off-site damage avoided (e.g., $/year or kg/ha)

None of these measures is simple to use in estimating reliably, and the overall effect of any technology could be a complex combination of them all. For example, a technology package emerging from a national research and development program could simultaneously increase maize yields, increase fertilizer costs and, through closer plant spacing and a shorter growing period, reduce soil erosion and hence reduce associated on-site and off-site costs (assuming there were no externalities associated with the increased fertilizer application). Output price changes are typically associated with increases in product quality, and also present some analytical complexities in the sense of a nonhomogeneous commodity at the market level (Macagno 1990).

The gross benefits accruing from research investments can be estimated by aggregating the different research effects expected across agroecological zones. The most satisfactory aggregation weights are the production values or areas within each zone–recognizing that production shares by zone may well change themselves as a consequence of research. As a final step, AEZs can be aggregated into administrative regions, on which basis market information is usually held. With the use of geographical information system (GIS) technology, this zone-to-region reaggregation is not a significant problem.

Our discussion to date has focused on the supply shifting or unit cost reduction effects of research. An assessment of the economic effects of research requires two additional, and jointly determined, parameters, namely the research and development lag time and the probability of research success. Obviously the deployment of all research resources to a single research problem could, with a reasonable degree of confidence, be expected to have relatively large effects in a relatively short space of time. Similarly, a problem researched with fewer, and perhaps less-skilled researchers, would probably provide less satisfactory results in a longer time frame. The joint determination of these research production function parameters is further discussed.

Technology transfer

The analytical framework being proposed is built on the concepts of disaggregating a research portfolio into agroecological or ecologic-economic zones and exploring the research impacts likely to arise in them as a consequence of alternative research investment options. This formulation begs many questions, one being the extent to which technologies developed for one zone can be transferred, with or without adaptation, to other zones–a process referred to in literature as *technology spillover* (Davis et al. 1987; Alston *et al.* 1993). Conceptually, this question is also valid for commodity-to-commodity and discipline-to-discipline spillover, but here we confine ourselves to technology spillover between zones.[3]

Technology spillover is important because the total impact of research in any zone is the sum of the impact of technologies that are directly targeted to the zone (if any) plus the additional spillover impacts (if any) that can be realized by the adoption of technologies developed for other zones. While the concept is relatively simple, estimation is complex–not least because it is difficult to establish (a) the potential performance of technologies across different zones, and (b) whether the spillover technology is a complement to or a substitute for existing or emerging technologies in the receiving zone. Moreover, the institutional and socioeconomic impediments to technology transfer may be significant and should, ideally, be an integral part of any research assessment procedure.

3 This discussion also ignores price spillovers, but these can be taken into account in the economic component of the research evaluation analysis (see Alston et al. 1993).

The extent to which technologies are potentially transferable relates to the agroecological "similarity" of sites and to the environmental adaptability range of specific commodities. Furthermore, it is also related to the environmental specificity of the technology. As polar examples, technologies that are *not site-specific* are potentially one hundred percent transferable, whereas technologies which are *totally site-specific* are zero percent transferable.[4] Where technologies are sensitive to environmental factors, the relative values of those factors between zones serve to indicate the likely limits of potential transferability. It seems plausible to estimate such relativities. However, the complementarity or substitutability of different technologies is a complex issue that is much less amenable to formal estimation.

Nonetheless, it should be apparent that the ability to make sensible estimates of the potential spillover effects of technologies between AEZs has major implications for resource allocation. A more efficient and flexible allocation of resources would be possible if the mechanisms of technology spillover between zones were better understood and could be integrated into the resource allocation process.

Strategic trade-offs

The effects of research (by whatever measure), the research and development time lag, the confidence with which these effects will be achieved, and the extent to which research outputs may spillover are all, to a greater or lesser extent, governed by resource allocation decisions. Furthermore, they are mutually interdependent. Thus, research managers face trade-offs between, for example, low-impact and high-spillover research or high-impact and low-spillover technology developments, while simultaneously trading-off any impact level against the duration of investment in specific research programs. Scientists could be asked to deliver short development cycle, low-impact or longer cycle and higher-impact technologies. The confidence levels of achieving specific levels of impact (as well as the impact level itself and its development lag time) could be improved in the long term by increasing resource allocation to staff education training, and improved infrastructural support and/or by improving the pool of available expertise through national and international institutional collaborative linkages.

These trade-offs, compounding those associated with the targeting of regions, zones, social groups, and production systems, are often too complex to make in an informed manner without proper analytical support. The research evaluation framework being outlined here is seen as a key element in such a support system.

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4 This terminology is preferred by Pardey and Wood (1993) to the roughly equivalent terminology that classifies research as "basic" (implicitly of broad applicability at the pretechnology level), and "adaptive" or "applied," which may imply a low level of spatial transferability.

Operational Consequences

The ability to undertake strategic research evaluation presupposes some insight into the range of agricultural production opportunities and constraints and their associated researchable issues. Furthermore, strategic level analysis largely avoids the important question of *how* research could be conducted. These are the concerns of operational management. Operational aspects of research management are beyond the scope of this LAC regional review, but the need for, and requirements of, analysis at this level must be recognized. Ideally, the conceptual framework of research evaluation should provide for a smooth methodological transition between regional/national strategic analysis and national/subnational operational analysis. Operational analysis should appear to be *zooming in* on the levels of spatial and research aggregation used at the macro level, for example, more specific definitions of a commodity by subtypes and varieties/cultivar groups, more detailed identification of technologies by specific problems/disciplines, and more detailed subdivisions of zones to acknowledge spatial heterogeneity within zonal aggregations used at the strategic level.

The two levels are not independent. The macro framework presented so far is appropriate at regional and national levels for supporting strategic decision making on priority setting and resource allocation by production system, geographical area (administrative region and/or agroecological zone), and major technology group. While avoiding the operational questions of research and experimental design, this macro analysis needs to be aware of the range of potential research opportunities and their likely effects–information that may best come from scientists and research managers working at the operational level. Thus, a two-way flow of information between the strategic and operational levels is essential.

Major responsibilities at the operational level include detailed research specification, experimental design, and selection of appropriate research sites, all of which have agroecological dependencies. The environmental specificity of certain types of research will often influence the selection of technologies or disciplines so as to maximize spillover potential. Experiments will be designed and sites will be selected within agroecological zones that are, in some sense, representative. In practical terms this means sites are selected that have no significant physical constraints or, alternatively, exhibit known and significant abiotic or biotic constraints (e.g., acid soils or pest/disease hot spots).

Table 2 summarizes the strategic and operational issues in research management discussed above and indicates the likely extent to which agroecological analysis may contribute to strategic decision making.

Table 2. Research evaluation and agroecological analysis.

	Potential contribution from agroecological analysis	Considerations/remarks
Strategic priority issues		
Technology targeting		
Where will *what* technologies be most appropriate, and for *whom*?	Identification of geographical areas –AEZs–expected to exhibit relatively homogeneous *physical* response to the application of new technologies. Zoning can take account of both production and environmental consequences.	(a) Most common zoning methods are summarized in Figure 1. (b) Importance of adopting compatible levels of aggregation/classification between environment, production systems, and research. (c) GIS is rapidly expanding zoning and analysis options.
Quantifying effects		
What is the likely level of economic effect (cost reduction, benefit) of new technologies on the targeted groups?	(a) Zones provide a basis for dialogue with scientists on expected impacts. (b) By using crop response and simulation models quantitative assessments can sometimes be made of research impact on potential production and environmental effects in each AEZ.	(a) Account should be taken of any changes in environmental adaptability that new technologies may be designed to achieve (i.e., changes in zone boundaries) (b) Even "physical" assessments of potential effects make important socioeconomic assumptions.
Spillover potential		
To what extent may technologies developed in or for one area be usable in, or adaptable to, other areas?	Identification of potential technology spillover by analyzing spatial patterns of productivity relativities as well as the physical production constraints that give rise to those relativities.	Same as "quantifying effects."
Operational research management issues		
Research problem selection		
What research problem and technology mix?	Analyze targeted and spillover impacts at disaggregated commodity, environment, and technology/discipline level. Direct estimation of likely impact of research, which seeks to alter agroecological responses.	Need for broad-based crop and livestock models-encompassing both productivity and environmental factors.
Experiment design		
What experiments and experimental designs?	Ensure proper mix of AEZs. Define spatial extent and severity of physical production constraints and degradation hazards.	Need for verification that AEZ groupings are appropriate.
Site selection		
Which experimental sites?	Ensure sites are representative of AEZ target zones.	Identify sites with no significant constraints or sites having specific abiotic, biotic, or degradation characteristics of relevance to the experiment.

RESEARCH EVALUATION AND AGROECOLOGICAL ANALYSIS: METHODS AND ISSUES

Research Evaluation

Research evaluation, as it is viewed in this report, seeks to quantify the effects of research in terms of its contribution to predefined research goals. Using such tools, research managers, scientists, and analysts can place a value on alternative research investment strategies in terms of their likely contribution to, for example, rural income generation (growth), income distribution (equity), and protection of the natural resource base (sustainability). These approaches can also be used to identify the likely opportunity costs, in terms of foregone output growth, of targeting research to address distributional or equity concerns. Alston, Norton, and Pardey (forthcoming) review the range of research evaluation options and the scope of their application in research priority setting and resource allocation. A practical, but not conceptual, distinction is made between evaluating the effects of past research investments (ex-post analyses or, more popularly, rate-of-return studies) and estimating the likely benefits that will arise from current or proposed research investments (ex-ante analyses). The analytical tools at the disposal of research analysts include congruency analysis, scoring/weighting systems, and a variety of ex-ante and ex-post economic surplus methods. To date, the explicit inclusion of agroecological considerations into these methods has been extremely limited.

Economic surplus models commonly estimate the annual benefit of research by viewing research-induced, technology effects as shifts in aggregate market supply curves. One such model, MODEXC, was developed at CIAT (Lynam and Jones 1984; Rivas et al. 1991).

For the applications proposed in this review, however, MODEXC has the drawbacks of not explicitly supporting any agroecological disaggregation, nor of supporting multiple markets, for example, multiple countries and/or administrative regions. Perhaps the most widely known model recognizing the multiple market effects of research was first formulated by Edwards and Freebairn (1981) and developed further to explicitly reflect agroecological aspects, by ACIAR (Davis, Oram and Ryan 1987). ACIAR's ex-ante economic surplus formulation adopted a set of AEZs (those defined by FAO's global AEZ study) between which allowance was made for potential technology spillover. This work has progressed even further (Davis, McKenney and Turnbull 1989; Pardey and Wood 1993). Improved specification of the agroecological component of the ACIAR model has been one of ISNAR's concerns, and their enhancements now support (a) dynamic definition of AEZs to match specific agroecosystems or agroecosystem clusters; (b) disaggregation of research into commodity subtypes, for example, rice into three ecotypes; irrigated, dryland, and swamp; (c) disaggregation of the (sub) commodity research domain by major technology groups such as genetic improvement, pest/disease control, and crop/animal husbandry; (d) variable levels of expected research impact by (sub-) commodity, technology type, and AEZ; and (e) an improved AEZ-to-AEZ technology spillover algorithm. These enhancements are under continuing development and are being used in part or in whole in ISNAR-supported national research evaluation and priority setting projects in Indonesia, China, and Argentina.

For the remainder of this report, it is assumed that some form of these multi-market models would provide a logical methodological starting point for the development of an analytical framework for strategic research decision making at the regional and country level in LAC.[5] The references should be consulted for further methodological principles of ex-ante economic surplus models. In summary, however, the models estimate the expected year-by-year stream of economic benefits to producers, consumers, and tax-payers arising from the application of new technologies to the production of individual commodities. These models require, at a minimum, the type of information summarized in Table 3. Enhancements to this basic model include other options such as autonomous growth of demand and supply, various government policies such as input and output taxes and subsidies, and variously more sophisticated adoption algorithms.

Table 3. Minimum data set for ex-ante economic surplus models with multiple markets and agroecological zones.

Research evaluation variable	Variable disaggregated by (Sub) Commodity	Technology	Region	Zone	Time dependent
Quantities produced	✔		✔		✔[b]
Quantities consumed	✔		✔		✔[b]
Price	✔		✔		✔[b]
Supply elasticities	✔		✔		
Demand elasticities	✔		✔		
Research (supply-shifting) effects	✔	✔	✔[a]	✔	✔[b]
R&D time lag	✔	✔	✔		
Probability of success	✔	✔	✔		
Adoption data (max. adoption level, timing)	✔		✔		
Spillover potential	✔		✔[a]	✔	

a Calculated by the evaluation model based on spatial aggregation weights (taken from a GIS).
b Calculated by the evaluation model after initial conditions are specified.

To implement this type of analytical framework requires data from a range of agricultural production, market, natural resource, research, and extension data sources, and clearly this represents a challenge to research analysts. From the methodological perspective some of the key analytical steps in the research evaluation process are

a. delineation of zones of potentially homogeneous technology impact
b. estimation of the direct effects of targeted technology in each zone
c. estimation of potential spillover effects

The remainder of this section will describe specific techniques that could be used to implement these three steps in the context of a LAC regional research evaluation frame-

5 The framework would also support the analysis of subnational regions as required.

work. These techniques are increasingly being embodied in quantitative algorithms, software products, and training materials that, together with the growing body of analytical expertise in the region, can significantly increase the capacity for quantitative support to research decision makers in LAC.

Zoning

Aggregation, classification, and technology

There are a number of fundamental difficulties with zoning, particularly at the level of regional analysis. Given that optimum land management and production methods can change on a field-by-field basis in agroecologically diverse areas, how is it possible to delineate meaningful zone boundaries at a regional or even a national scale? This trade-off between scale and accuracy is not a new problem either to information science or to natural resource specialists, and historically the solution has been to classify environmental characteristics in ranges appropriate to (a) the application for which the classification is being made, for example, delineation of areas suitable for food crop production, or (b) the natural occurrence of environmental patterns (environmental clusters). At high levels of aggregation it is customary to identify and group commonly occurring associations of ranges, as in soil science, where soil mapping units frequently represent complexes or associations of different physiographic units and/or soil types. Since these associations are usually quantified in proportionate terms, precise spatial definition is lost, but information on the heterogeneity occurring within each mapped unit is retained for subsequent analysis.[6] Another important principle involved is to maintain compatibility between the hierarchical (aggregation) level of environmental characterization and the hierarchical (aggregation) level of production system characterization. Thus, it would be misleading to match the precise environmental requirements of a specific crop cultivar with an agroecological zoning scheme designed for application at a continental scale, a scheme in which zones are likely to be highly heterogeneous from the perspective of the cultivar.

Two important technologies are rapidly changing perceptions and practices on the subject of zoning; these are geographical information systems (GIS) and remote sensing. Much of the historic need for classification was related to the constraints of manual analysis and mapping whereby early classification (reduction) of the information content was essential to make analysis tractable. Classification results in the delineation of more contiguous zones and, thus, a simplified mapping process. Raster-based GIS and remote sensing technologies support the computer-based storage, analysis, and "mapping" of very large quantities of spatial data. Computer-derived images are made up of

6 For example, the mapping unit "Bh12-3c" delineated on the FAO/UNESCO soil map is made up of three proportional elements: soil type Humic Cambisol with heavy textures and steep slopes for 60% of the unit, soil type Orthic Acrisol with medium texture and medium slopes for 30% of the area, and soil type Dystric Fluvisol with medium texture and gentle slopes for 10% of the area.

individual rectangular pixels, each representing, in the case of satellite data, 100 to 400 square meters at the most detailed level. Adjacent pixels can depict totally different agroecologies. Similarly, point data from climate stations and soil pedons are increasingly being stored in their original format and only analyzed and spatially interpolated to meet the requirements of each new application, thus minimizing information loss or distortion associated with classification. These developments do not undermine the usefulness of classification and zoning, but, rather, they result in the practice of classifying and zoning much later in the analysis cycle, often only for the purposes of output presentation.

A final issue concerns the type of zoning information generally available to research analysts compared with that ideally required to support research evaluation. Agroecological analysis can delineate zones that are likely to exhibit a homogeneous physical response to the application of new technology. However, the actual (or realized) response is limited by the market, infrastructural, institutional, cultural, and other conditions governing technology adoption and use. If purely agroecological zoning criteria are used, then the research evaluation analysis must use other means to estimate *actual* adoption/impact that may occur within AEZs of uniform *potential* impact. For this reason, inter alia, it is becoming more usual to incorporate adoption-related characteristics into the spatial zoning process, that is, to make combined ecologic-economic zones.

Zoning methods

Issues of scale, purpose, and the availability of such technologies as GIS and remote sensing have all influenced the approaches taken to zoning. Furthermore, the complexity of zoning is, as we have seen, increasing as the defining criteria (spatial overlays) increase. The earlier work, such as FAO's AEZ study for LAC (FAO 1981) used relatively few thematic layers to delineate the agroecological boundaries to production potential. While there is still great scope for improving the agroecological component of spatial analysis at the regional level, there is growing acceptance that many other spatially varying factors governing both production potential and technology adoption warrant incorporation into the zoning process.

A related but separate issue from the number and type of variables used to delimit zones is that of the particular zoning method adopted. There are many approaches to agroecological classification and zoning (Young 1987) and, with respect to LAC, four of these, summarized diagrammatically in Figure 2, are considered most relevant:

a) Fixed zones

On the basis of an expected range of potential production systems and environmental degradation hazards, a general set of environmental classification criteria are defined. When applied to the land resources database of an area, the criteria translate into spatial boundaries that delineate zones. These zones are fixed regardless of the actual land use or agroecosystem options that are eventually tested. The FAO

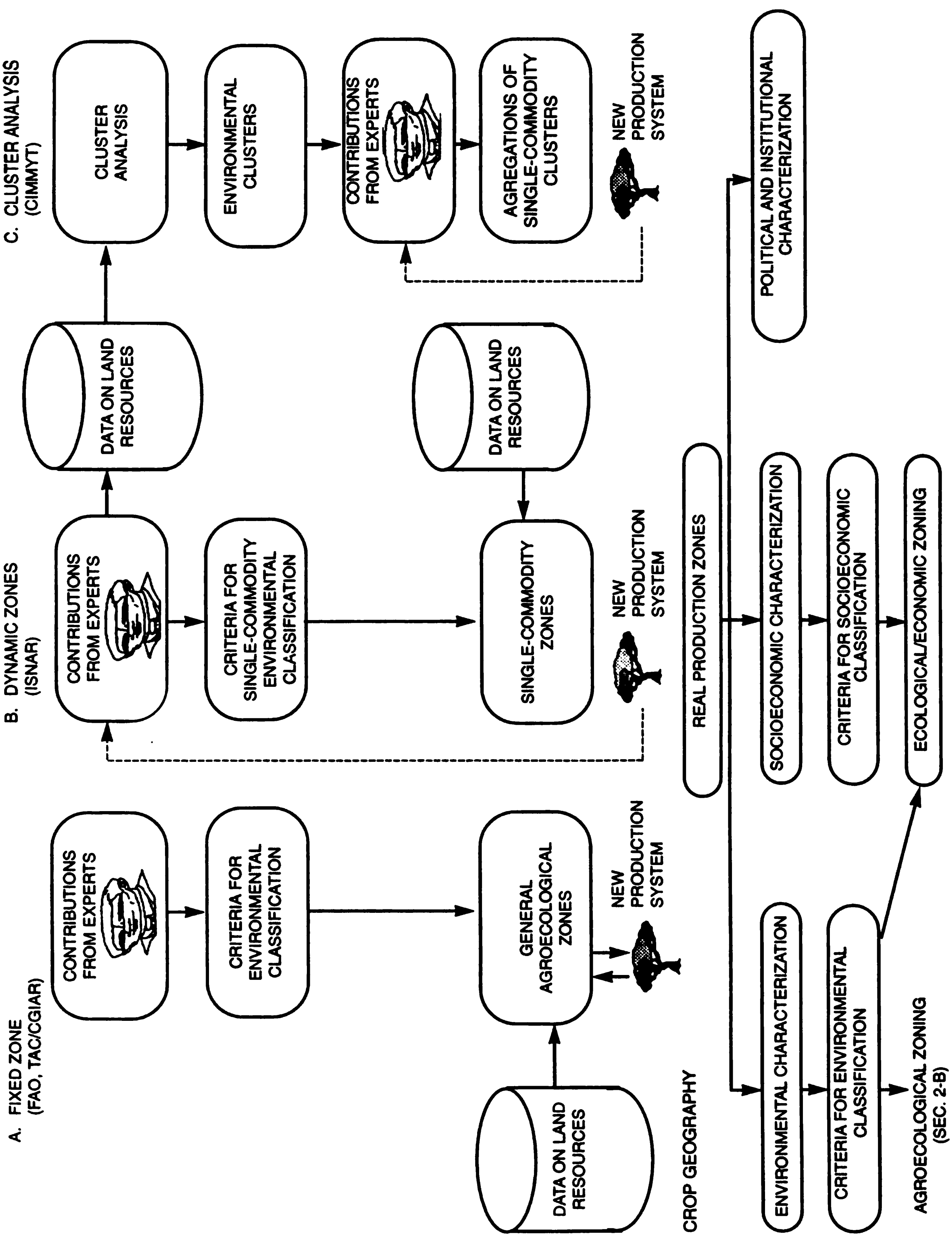

Figure 2. Approaches to agroecological zoning.

AEZ methodology adopts this fixed approach to zones.[7] Because ACIAR's research priority study used FAO's AEZs, the fixed zone approach was inherent in their original research evaluation methodology.

b) Dynamic zones

Here adaptability and degradation criteria are identified separately for each potential production system. Thus, a different spatial definition of zones, that is, a new zonal map, is produced for each individual or group of production systems. This approach has been used in ISNAR's collaborative ex-ante research evaluation project with the Ministry of Agriculture in Indonesia.

c) Cluster analysis

Here the starting point is not potential production systems, but the land resource database. Although conditioned by the selection of zoning variables and the statistical control parameters, an otherwise unhindered statistical grouping of environmentally similar clusters is obtained. Once defined, these clusters can be interpreted by agronomy/land evaluation experts to assess their relevance to specific production systems/land uses.

d) Production geography

In this approach the starting point is the actual distribution of production. This distribution can be characterized from a number of perspectives including agroecology, socioeconomics, and the institutional and policy environment. The characteristics so identified can then be used to delineate zones in other geographic areas.

Comparison of zoning methods

All of the above methods have their strengths and weaknesses. The fixed and dynamic zone methods are conceptually very close. An extremely disaggregated set of fixed zones–that is, many classification criteria and, hence, zone boundaries–could conceivably be aggregated into (dynamic) production-specific zones for each new production system. In practice, however, classification boundaries for fixed-zone systems tend to be oriented to general cartographic needs and seldom coincide with the requirements of any individual potential production system. On the other hand, the criteria used for dynamic zoning are selected to correspond with the agroecological thresholds related to specific production systems.

7 The fixity of zones is not inherent in FAO's AEZ concepts, but represents the way in which the concepts have been implemented in the original global study and in various subsequent country level studies.

Before the advent of computer-based GIS, zones were manually defined. Fixed zones then had the distinct advantage that zoning was performed only once, regardless of the number and type of production systems. The significant disadvantage, however, is that the zones so delineated may have considerable spatial mismatch with the actual requirements or tolerances of specific production systems. The dynamic method overcomes this problem since it redefines zones for each production system (or group) to match its precise requirements,[8] but it does have the disadvantage of requiring a capability to update zones as new production systems are analyzed. Updating involves the addition of delimiting criteria by digitizing or spatial interpolation. Dynamically defined zones, by virtue of their more precise criteria, should not only provide better spatial definition, but should also display greater homogeneity in their response to research.

Cluster analysis takes a fundamentally different approach by not predefining classification boundary values, but by defining only a set of characterization *variables* from which statistically significant environmental "cluster" boundaries (i.e., classification criteria values) are estimated. Expert judgment is then used to match defined clusters with production system requirements or tolerances to determine some acceptable aggregation of clusters that have broadly similar production system responses. This is not always easy. Experts are required to make judgments in a multivariable domain (compared with fixed and dynamic zones where variables are treated independently);[9] secondly, there is not necessarily a close correspondence between the naturally occurring agroecological clusters and the specific requirements of production systems. There are also some theoretical and practical difficulties in the statistical analysis itself, such as the choice of "distance" algorithm and the user specification of the number of clusters, both of which affect the clustering results. Nevertheless, the method does help to identify naturally occurring clusters that, by virtue of their size and/or location, could become the subject of research and development. Thus, cluster analysis is well suited to locating potentially significant environmental niches, and can help to recognize mismatches between the adaptability ranges of, for example, current germ plasm and environmental clusters occurring in zones to which that germ plasm may be targeted.

Cluster analysis is somewhat like the fixed zones approach if analysis for a new production system is made by a reinterpretation of existing cluster groupings, rather than by totally redefining cluster boundaries. Cluster analysis is a means of aggregating environmental space. The only way in which the clustering process is related to a specific production system is if the selection of cluster variables is production-system biased. In this case, there is scope to redefine cluster variables and, hence, clusters on a production system basis.

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8 The limits of precision are defined by (a) the extent to which the production system requirements or tolerances are known, and (b) the level of aggregation inherent in the underlying environmental data.

9 This is not to say that the independence (*ceteris paribus*) assumption is more scientifically defensible—rather that it has proved a more practical way of eliciting expert opinion on crop requirements or tolerances.

The production geography approach is manpower intensive, but does (theoretically at least) allow for the complete characterization of production. In this sense, it comes closest to the ultimate goal of identifying areas of homogeneous technology impact including adoption.[10] However, the approach is by definition limited to current practices, practices that do not necessarily provide reliable indicators of the likely impact of new technologies. For example, research may seek to shift the environmental adaptability range of a crop or to improve its tolerance to geographically specific pests and diseases. In this case, the potential impact of the new technology may define a significantly different production geography. Alternatively, the crop geography approach may be seen as a relatively rigorous scientific attempt to determine productivity, adoption, and, to some extent, sustainability criteria that could be used in any of the ways described above to help delineate zones beyond the current areas of production.

Assessing the Direct Effects of Research

Zoning is a means of bracketing the spatial extent of homogeneous areas with respect to the effects of new technologies. For the purposes of research evaluation, however, it is also important to quantify the likely level of impact within each homogeneous zone. In the section on technology impacts we saw some of the ways in which research effects can be measured, with the note that, for economic surplus methods, they need to be expressed ultimately as a reduction in the unit cost of production.

In an ex-ante setting, since experimental data will be limited or nonexistent, there are essentially two methods of estimating likely research impacts: by expert elicitation or by some form of quantitative algorithm. Expert elicitation is labor intensive and demands the willingness of scientists to participate in an essentially empirical review of their scientific endeavors. However, the elicitation process, an informal Delphi procedure, does allow experts to take into account complex and nontechnical factors that would otherwise be difficult, if not impossible, to represent in a modeling framework. The elicitation approach is also amenable to exploring important disaggregations of the research domain, for example, by eliciting expected impacts on the basis of important technology groups such as genetic improvement, pest/disease control, and crop/animal husbandry. Such a framework for disaggregated expert elicitation has been described by Pardey and Wood (1993).

Analytical impact estimation has proved possible mainly on the basis of projecting research-induced changes in various partial productivity measures such as changes in output per unit of land, labor, fertilizer, and so on. These productivity estimators can be used to infer measures of unit cost reduction. However, the major limitation in this approach is to find a range of practical models that can address all of the various ways in which productivity could be enhanced by new technologies. To the extent that tech-

10 A closer approximation to this objective could also be obtained by including appropriate variables in any of the other methods.

nologies may seek to change the agroecological adaptability of crops, for example, with respect to drought or frost tolerance, then various types of crop growth models may be appropriate. Similarly, environmental degradation models could be used to assess some of the likely effects of research on the environmental consequences of agricultural production. At a practical level, however, the capacity to make routine ex-ante impact assessments on an analytical basis appears limited for the foreseeable future, and expert elicitation seems likely to remain the method of choice.

One significant limitation of the elicitation approach is the tendency of scientists to overstate the likely impacts of their work. Given research and development time lags of 4 to 12 years, there may be little incentive to be cautious in their expectations. One means of bringing more objectivity into the assessment is to seek the independent review of research impact estimates (e.g., independent from the scientists proposing or undertaking the research). Another is to calibrate expected impacts with, at best, results from ex-post evaluation studies of the effects of research or, otherwise, historic productivity trends for the commodity of interest. Productivity trends serve as an upper bound to past research achievements since they include the impact of factors other than research.

Whatever method is used, it is important to distinguish whether the impact analysis is assessing only *potential* impact (assuming full adoption), or *realizable* impact that takes into account technology adoption regimes.

Assessing the Spillover Effects of Research

The basic choices in assessing potential technology spillovers are the same as for assessing the direct effects of research, but in this case there is more scope for some type of analytical solution. While the direct effects of research need to be assessed on an absolute basis, potential spillovers are required only in relative form, for example, zone A's technology would likely have 60% of its zone A impact if adopted in zone B. Analytical approaches are often built around the assumption that yield relativities between zones can be used as a proxy for spillover potential (Patamawadee, Setboosarng and Arepagorn 1991). Thus, in the case quoted above, the change in zone B's yields would typically be 40% lower than the change in zone A. Even assuming this was a reasonable assumption in transferring technologies from zone A to zone B, there is little credible basis to accept the inverse relationship, that is, that zone B's technologies would have a 66% higher impact in zone A than in zone B. Spillover potential must be calculated in both directions and this assumption implies that a matrix of zone-to-zone spillover coefficients would be symmetric. Furthermore, it has been the practice to set the leading diagonal elements to unity on the basis that zone A's technology should always be able to "spill" perfectly into zone A (Davis 1991), and that the off-diagonal values have values in the range 0 to 1.0.

Practical experience has shown that most of these assumptions are questionable. Firstly, asymmetry in spillovers appears common. One rationale is that technologies developed for zones that have little or no agroecological constraint probably have little agroecology bias (environmental specificity) and may therefore "travel well" to less favorable zones. Conversely, technologies developed for zones facing severe agroecological constraints would presumably be addressed, in part or in whole, to overcoming those constraints and, therefore, are less likely to have a corresponding cost of production (or yield) effect in zones where those constraints do not apply. On the question of coefficient values it has been shown that technologies targeted to one zone may actually perform better in a different zone. For example, many small ruminant technologies in Java are targeted to the coastal plains to promote product diversification in predominantly rice growing areas. However, those same technologies have much greater impact in the cooler highlands where the general health and prolificacy of small ruminants is much better. Thus, the spillover coefficient from lowland to highland is greater than unity (and, conversely, highland to lowland is probably significantly less than unity). Finally, for reasons of heterogeneity within zones it is possible that technologies targeted to one zone may be applicable less than perfectly in some parts of that zone. Thus, if zones are made up of environmental associations (see the zoning section "Aggregation, classification, and technology") technology impacts may be significantly reduced in some of the more agroecologically unfavorable components of the association.

It is widely considered that early estimates tended to overstate technology spillover impacts. Problems arise in assessing the extent to which a potential "spill-in" technology is superior to existing or emerging technologies in receiving zones. Linked with this is the issue of complementarity or substitutability of research (see "Technology Transfer" section). In discussing both of these issues, Pardey and Wood (1993) suggest that if potential spillovers are elicited or estimated according to disaggregated technology groups, for example, germ plasm spillover potential or crop management spillover potential, then a conservative rule-of-thumb is to view similar technologies as substitutes, but dissimilar ones as complements. A completed example of impact assessment using this approach is presented in Box 1.

REGIONAL EXPERIENCES, ISSUES, AND RECOMMENDATIONS

The preceding sections have highlighted some of the conceptual and practical issues involved in developing a research evaluation framework appropriate for the regional and subregional level in LAC. This section reviews some of the regional experiences to date in the fields of agroecology and research impact assessment, as well as the existing institutional and organizational structures that are available to support the future development of this work. Despite the significant political, institutional, and technical challenges that a truly regional approach to research evaluation would present, there are many reasons to believe that it is both feasible and worthwhile. One major cause for optimism is the history of regional and subregional research collaboration, coordinated and nurtured by IICA, in particular through its Technology Generation and Transfer Program.

The sections to follow deal with some specific areas of regional concern, along with a brief description of the type of methodological enhancements that would be necessary

Box 1: A worked example of calculating the direct and spillover effects of technology.

This example estimates the effects of research for a single zone (A), assuming the existence of two zones (A and B) to which research is simultaneously targeted. Expected targeted effects (e.g., unit cost reductions) and spillover coefficients are assumed to have been elicited on the basis of two major research technology thrusts, namely germ plasm improvement and crop management.

To assess total effects it is assumed that "like" technologies are potential substitutes (so that only the largest effect will be selected) whereas "unlike" technologies are complements (so that the effects are considered additive).

	Expected targeted effect[a]	
	Zone A	Zone B
	(dollars)	
Germ plasm improvement	2	3
Crop management	3	6

[a]Measured, say, as reductions in production costs per unit of output.

Spillover matrix: germ plasm improvement

	To Zone A	To Zone B
From Zone A	1.0	0.5
From Zone B	0.5	1.0

Spillover matrix: crop management

	To Zone A	To Zone B
From Zone A	1.0	0.66
From Zone B	0.66	1.0

Potential spillover from B to A

Germ plasm improvement = \$3 x 0.5 = \$1.5
Crop management = \$6 x 0.66 = \$4

Total effect in zone A (direct and spillover)
= max. germ plasm (2, 1.5) + max. management (3, 4)
= \$6

The total impact in zone A of \$6 with this algorithm is much more realistic than that of \$10.5 obtained assuming all spillovers are complementary (as the Davis, Oram and Ryan (1987) approach appears to do). As the number of zones in which research is being done increase, it is more likely for potential spilling effects to be grossly overestimated if no attempt is made to discern substitutable from complementary technologies. In the example shown, zone A germ plasm technology would be applied in zone A, but zone B crop management practices would be used in zone A since, even after discounting for spillover effects, these technologies are expected to reduce per unit costs of production by \$4 in zone A compared with the \$3 unit cost reduction of the best of zone A's own crop management technologies.

to properly address existing or emerging regional issues. Finally, suggestions are made on how the proposed quantified research evaluation framework could evolve, with special emphasis on the enhanced role of agroecology within the overall framework.

Regional Experiences

In the fields of both agroecological analysis and research evaluation the LAC region, as a whole, has much expertise and experience, while on a country-by-country basis, particularly in some of the smaller NARSs (national agricultural research systems) of Central America and the Caribbean, a good deal of variation appears to exist.

Characterization and classification of space

Almost without exception, both NARSs and regional IARCs (international agricultural research centers) have experience in agroecological classification and mapping, and some are already familiar with the integration of data on the socioeconomic classification of space. Such activities are supported by rapidly growing familiarization with GIS and remote sensing technologies, the regional availability of satellite receiving stations, and good access to sources of data and expertise beyond the LAC region itself.

The region is rich in its share of classification systems, zoning studies, and various forms of land resource appraisal. At the *agroclimatic* level, the region is the home to two extensively used systems, those of Papadakis (1961, 1966, 1970, and 1975) and Holdridge et al. (1971). Papadakis developed a hierarchical, multidigit decimal coding system to classify agricultural environments throughout the world. The classification scheme is made up of fairly complex combinations of temperature and humidity ranges and patterns of occurrence that result in many hundreds of possible classes. The Holdridge system was developed specifically for the tropical zones of Latin America, primarily for forest areas, but it has found a much broader application with natural resource scientists in the region. Based on a triangular nomogram, the system relates annual rainfall and temperature (assuming a fixed potential evapotranspiration ratio) to various climatic groupings defined in terms of indigenous, tropical-American, vegetation zones. A third system in use at the regional level is the agroclimatic classification system developed by FAO to support its global AEZ study (FAO 1981). The method defines agroclimatic zones on the basis of thermal zones (called "major climates" in the early FAO documentation) on which were superimposed isolines of the "length of growing period" (LGP). LGPs were calculated from rainfall observations and potential evapotranspiration estimates in a simple soil moisture accounting model using a fixed "reference" soil moisture holding capacity of 100mm.[11] Both the Papadakis and FAO systems have the

11 Although at the country level FAO studies have used additional overlays, e.g., LGP pattern (year-to-year variation of LGP) in Mozambique, Kenya, and China, and others in Bangladesh. Furthermore, the thermal zone and LGP class boundaries are not fixed. Thus, country specific classifications and the ecoregions proposed for TAC/CGIAR adopt a variety of agroclimatic aggregations.

advantage of being applicable throughout the LAC region, and FAO's system has the additional advantage of being available in digital map format.

However, advances in information technology in general, and GIS and remote sensing in particular, are eroding the need for fixed classification systems. It is now cost-effective to store and manage large volumes of data and to analyze and spatially interpolate them to suit the precise requirements of specific applications. A good example of this approach is CIAT's METGRID system which is a large climate station database that is periodically reinterpolated onto a raster grid in an unclassified format (see Jones 1990). These data support all kinds of agroclimatic analyses including, if necessary, classification according to any or all of the Papadakis, Holdridge, or FAO systems. There are many examples of agroclimatic zoning studies in LAC. For example, at a regional level there is the agroclimatic component of FAO's AEZ study (FAO 1981), at a subregional level there is the agroclimatic study of the Andean zone (Frere et al. 1975), and at the national level there is the agroclimatic map of Chile (INIA 1989).

The systems described above are for general climate classification, albeit in the agricultural and forestry sectors. However, there are also plenty of examples of production system or commodity specific agroclimatic classification and zoning systems. Perhaps the most widely known are the mega-environments used by CIMMYT to stratify their breeding and management programs at the highest level. Although the wheat mega-environments are determined by climatic factors, the maize mega-environment classification also includes color and texture properties of the maize grain, and both systems utilize temperature and elevation criteria in ways that appear to lead to nonuniqueness in zoning. CIMMYT has recently established a GIS unit to help clarify some of the practical applications of the mega-environment concept, and to help expand commodity specific environmental analysis at macro and micro levels.

To identify AEZs as they are defined in this report requires recognition of physiographic and edaphic heterogeneity within agroclimatic zones. At the regional scale, FAO's AEZ data sets combine the FAO agroclimatic classification system with the 1:5M FAO/UNESCO Soil Map of the World (FAO-UNESCO 1974 and 1975). Once the mapping unit associations are decomposed, the FAO AEZ database comprises AEZ characterization by country, thermal zone (14), length of growing period (27), soil type (132), soil slope (3), soil texture (3) and soil phase limitations (20), where bracketed figures indicate the number of classes. However, because the soil-related information is derived from a mapped soil association, the spatial definition of individual entries below the mapping unit level is lost. Nevertheless, information on soil heterogeneity is retained for analytical purposes. A much more comprehensive data set has been compiled by CIAT at a scale of 1:1M of the land (including climate) resources of tropical America (Cochrane et al. 1985). The maps associated with these data sets have been digitized in vector format (ARC/INFO) and subsequently rasterized. FAO's AEZ data is known to be available on a 10-minute (approximately 18km at the equator) grid, while CIAT's land resources data is rasterized on a 5-minute by 4-minute grid. A major effort is also being made within the region to implement the UNEP/ISRIC *SOTER* soil and terrain digitized database at 1:1M scale (UNEP/ISRIC 1990). Following successful pilot studies, subregional groups have assumed the responsibility to secure funds and proceed with implementation according to a standardized methodology. The time scale for availability of *SOTER* data sets is unclear, since funding remains uncertain. In addition to the regional and subregional published work of FAO and CIAT, there is a wealth of data at the national level from a wide variety of land resource assessment and agroecological zoning exercises, usually published at a scale of 1:500,000 to 1:1M. One representative example is the Agroecological Map of Colombia, published jointly by the Agustin Codazzi Geographical Institute (IGAC) and Instituto Colombiano Agropecuario (ICA) at a scale of 1:500,000 in 1985. Additionally, there are many other land resource assessments in which some form of agroecological zoning is implicit, such as the 1:1M scale land resource capability assessment of Argentina (UNDP/Ministry of Agriculture 1986).

In addition to its extensive work in land resource assessment, CIAT has pioneered the development of crop-specific characterizations of space with its crop geography-related activities. This approach has gradually been extended far beyond agroecology into characterizations of the socioeconomic and market aspects of production systems and determinants of technology adoption. CIAT has focused on its mandated commodities, including rice, cassava, beans, and tropical pasture; perhaps the most widely published of these activities is its work on cassava production systems (Carter 1986, and Carter and Jones 1989).

A compilation of maps in computerized digital format generated by some of the studies described above has been prepared as a companion volume to this report (Wood and Panghudi 1993). Samples of important thematic maps drawn from this volume are presented in Figure 3. The figure illustrates FAO's agroclimatic variables: (a) thermal zones, (b) length of growing period, (c) an aggregation of FAO-UNESCO soil information prepared by CIAT,[12] and (d) a mapping of land accessibility also prepared by CIAT. It is easy to imagine, even at this scale, the enormous range of potential production environments represented by the superposition of these themes alone.

CGIAR ecoregions

Of particular importance in a regional research policy and priority setting context is the appropriate division of labor and research emphasis between national, regional, and international research agencies. In this regard the ecoregional framework that supports current CGIAR thinking about the system's structure, problem focus, and its relationship with NARSs is of special interest. In its present formulation, this classification scheme fails to account for variations in soil and terrain attributes but captures important agroclimatic characteristics.

Table 4 provides a summary of the names, classification criteria, and "global" incidence of the ecoregions.

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12 CIAT took dominant soil types as representative of each FAO-UNESCO mapping unit, but the image presented here has been aggregated to the level of soil group. The image is thus two levels of aggregation removed from the associated computerized database of soil information.

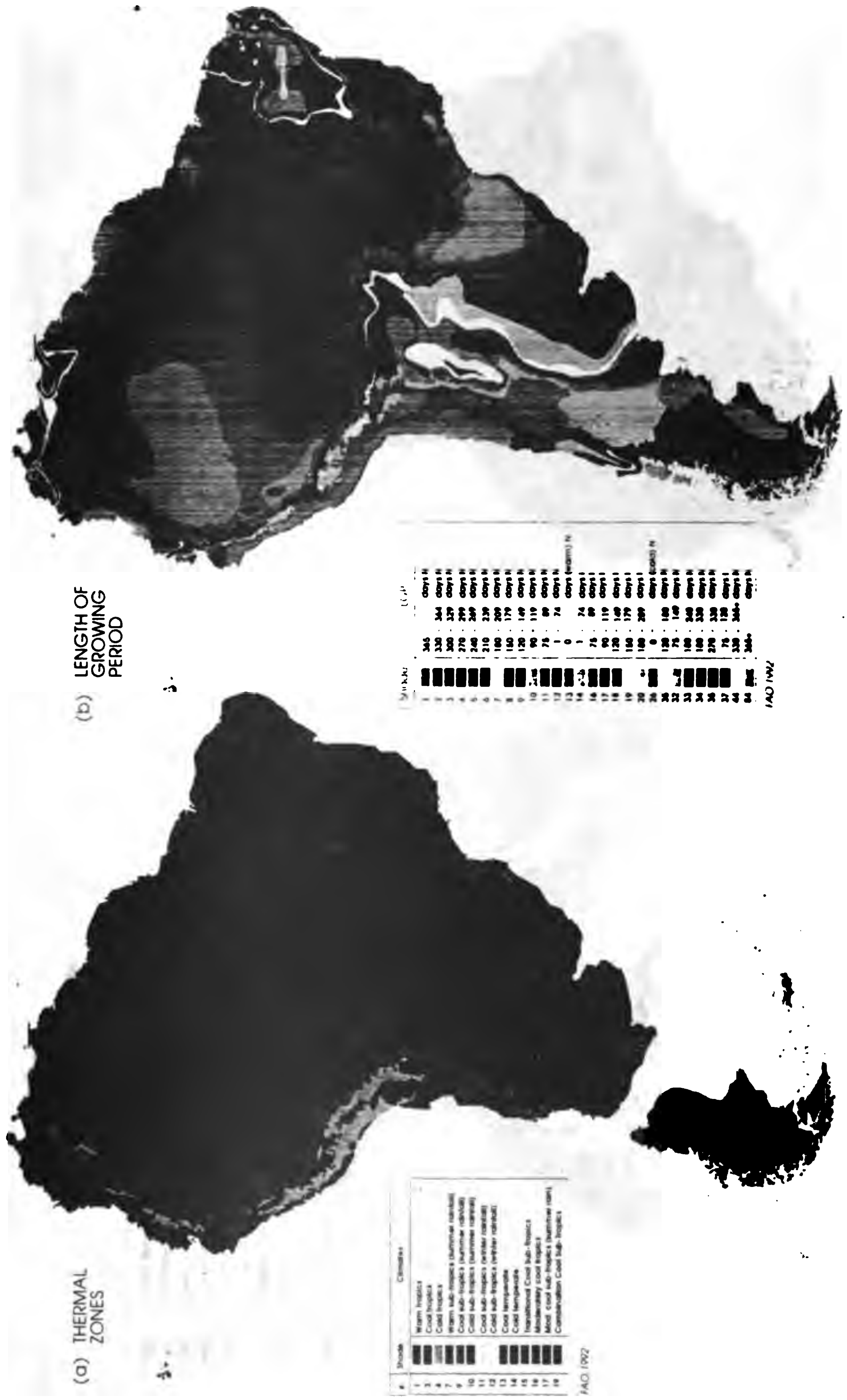

Figure 3. Sample thematic components for GIS-based analysis to support regional research priority setting.

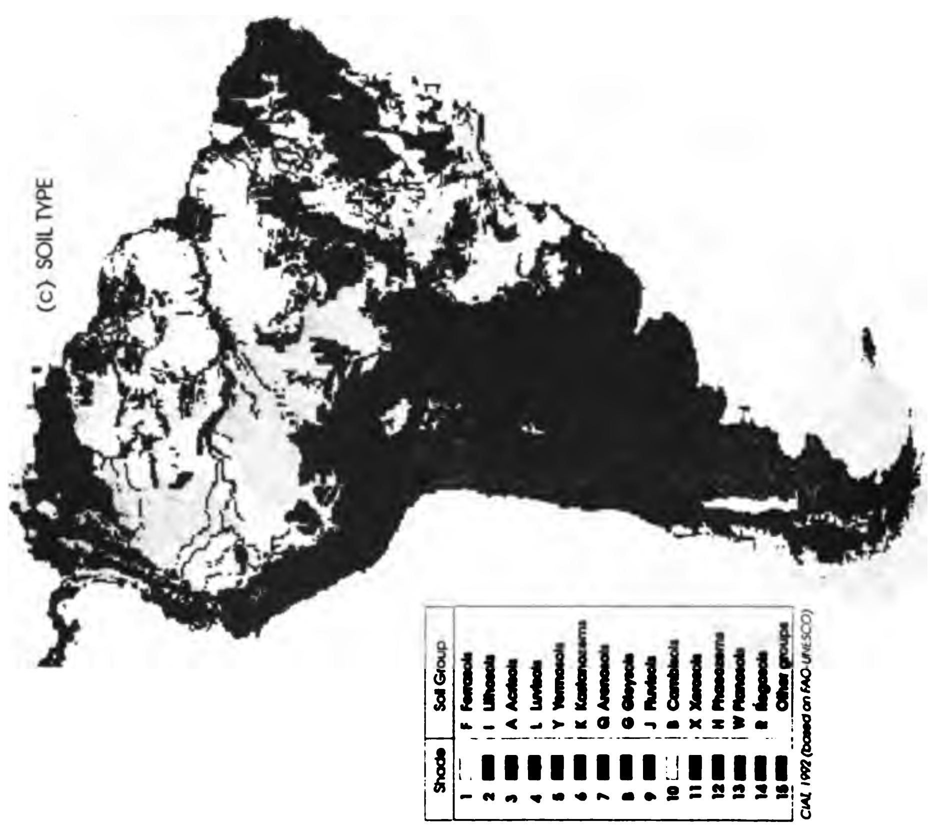

Figure 3. (Continued).

Table 4. CGIAR agroecological zones.

Zone/region	Name	Length of growing period	Temperature	Share of LDC arable land	Share of total arable land
Less-developed countries		*(Days)*		%	%
AEZ1	Warm, Semiarid Topics	75-180	> 20°C all year round	21.4	11.3
AEZ2	Warm, Subhumid Tropics	180-270	> 20°C all year round	14.1	7.4
AEZ3	Warm Humid Tropics	270-365	> 20°C all year round	14.1	7.4
AEZ4	Cool Tropics	75-365	5-20°C during growing period	4.9	2.6
AEZ5	Warm, Semiarid Subtropics (Summer Rainfall)	75-180	> 20°C during growing period	11.8	6.2
AEZ6	Warm, Subhumid Subtropics (Summer Rainfall)	180-270	> 20°C during growing period	3.7	2.0
AEZ7	Warm/Cool Humid Subtropics (Summer Rainfall)	270-365	> 20°C during one part of the growing period and 15-20°C during the other	9.8	5.1
AEZ8	Cool Subtropics (Summer Rainfall)	75-365	5-20°C during growing period	8.3	4.4
AEZ9	Cool Subtropics (Winter Rainfall)	75-365	5-20°C during growing period	11.9	6.3
More-developed countries				–	47.5

Note: Zones that have a mean monthly temperature, corrected to sea level, above 18°C for all months have been classified *tropical.* Zones with one or more months below 18°C but above 5°C are *subtropical,* and zones with one or more months below 5°C are *temperate.* Length of growing period has been defined as the period (in days) during the year when rain-fed available soil moisture is greater than the half-potential evapotranspiration (PET) rate. It includes the period required to evapotranspire up to 100m of available soil moisture stored in the soil profile. It excludes any time interval when mean daily temperature is less than 5°C. Zones with mean daily temperature greater than 20°C during the growing period have been classified as *warm.* Zones with mean daily temperature between 5°C and 20°C are *cool,* below 5°C are *cold,* and if one part of the growing period has temperatures greater than 20°C and the other is between 5°C and 20°C, they are classified as *warm/cool.* Zones have been classified as *arid* if the length of growing period is less than 75 days, as *semiarid* if the range is between 75 and 180 days, as *subhumid* if the range is between 180 and 270 days, and as *humid* if the range is greater than 270 days.

Table 5 shows, for many of the larger LAC countries, the proportion of arable land that falls within a particular AEZ. Clearly, this is a coarse classification scheme. Five of the 20 countries in the region have been assigned to a single agroclimatic zone and 7 countries have been assigned to just 2 zones.

Table 5. Proportion of arable land by CGIAR ecoregions for LAC (percentage).

	Zone								
Country	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Argentina				8	16	5	69	2	
Bolivia	18	14	19	49					
Brazil	7	29	20		45				
Chile							100		
Colombia			32	68					
Costa Rica		7	10	82					
Cuba	58	42							
Dominican Rep.		100							
Ecuador	27	3	21	50					
El Salvador		41		59					
Guatemala			3	97					
Haiti	100								
Honduras			29	71					
Mexico	12	15	17	27	29				
Nicaragua			100						
Paraguay		2			98				
Peru			6	94					
Suriname		100							
Uruguay									100
Venezuela	38	46	16						

Source: Kassam 1991.

Note: For definitions of the different agroecological zones see Table 4.

Figure 4 presents agricultural land and labor productivity patterns for the LAC countries reaggregated into the nine CGIAR AEZs defined in Table 4.[13] This represents a crude attempt to "overlay" the nine agroclimatic zones on country-specific, agricultural

13 Because of data limitations, particularly for the smaller countries, only 20 countries are included in this analysis, but those countries included account for an overwhelmingly large share of the region's total agricultural output.

input and output data. Without data on the spatial distribution of labor and output within countries having multiple AEZs, we simply assigned national totals of labor and output to each zone according to the level of labor and output per hectare in the country as a whole. While this does not provide any new information on productivity measures across AEZs within one country, aggregating productivity measures across AEZs in different countries provides a rough measure of the impact of agroclimatic variation on productivity.

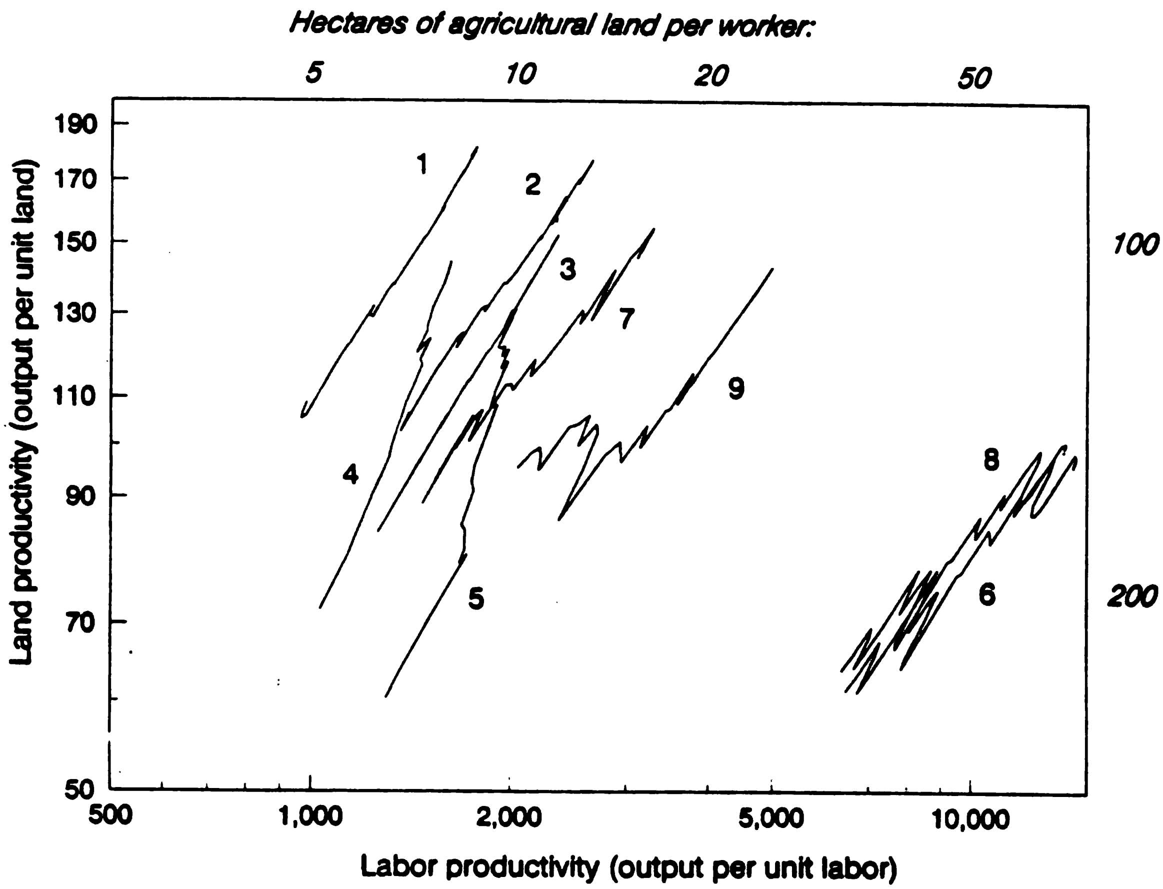

Figure 4. Regional comparison of agricultural land and labor productivities by agroecological zones, 1961-1990.

Source: Adapted from Craig, Pardey, and Roseboom (1992).

Note: Numbers in figure refer to agroecological zones defined in Table 4. Output is measured in terms of "final" agricultural output expressed in 1980 agricultural purchasing power parity (PPP) dollars. Land is the stock of total hectares of land in agriculture (whether they be arable, permanently cropped or permanently pastured), and labor is the economically active agricultural population.

The horizontal axis in Figure 4 measures labor productivity, the vertical axis land productivity, and the dotted (45-degree) lines represent constant land-labor ratios. The graph shows that across zones in Latin America and the Caribbean there were relatively small differences in land productivities, but quite marked differences in levels of output per worker. The pampean and cool subtropical zones of the Southern Cone (AEZs 9 and, particularly, 6 and 8) have land-labor ratios ranging from two to seven times higher than the regional average of 19 hectares per worker. The length of the graph is directly related to the growth in productivity, so there appear to be no marked differences across zones in this regard. Nevertheless, all of these zones exhibited some productivity growth, so that the lower, left-hand end points of all the graphs in every case corresponds to the beginning of the period. A flatter graph indicates a greater substitution of land for labor (e.g., zones 6 and 8) and a steeper one indicates that labor is being substituted for land (e.g., zone 5).

Using these ecoregions to develop broad characterizations of the developments within LAC agriculture does serve to illustrate that agroclimatology plays a significant role in shaping the pattern of productivity growth in this part of the world.[14] But there is a good deal of significant heterogeneity that these zones do not attempt to capture, not least from the variability of physiography and soil. Certainly these zones cannot pretend to define tolerably homogeneous production areas in terms of the productivity enhancing prospects of a particular line of research on a particular commodity, nor the impact of that research on the environmental consequences of agricultural production. To this extent, it is difficult to envisage the utility of these ecoregions even in the context of a regional priority setting exercise–which in turn begs the question of the relevance and utility of the currently defined ecoregions to the CG (Consultative Group) system itself. This does not, however, negate the idea that agroecological characterizations of space provide powerful means of analyzing the variability of research effects and their spillover potentials. But it does appear that the CG ecoregions are too aggregated to be of much practical value, except perhaps for such global assessments as the original FAO study that generated the agroclimatic databases from which the ecoregions are drawn. However, it should be noted that in the FAO study well over one hundred combinations of thermal zone and length of growing period were mapped in the LAC region alone, compared with the CGIAR's nine ecoregions.[15]

Research evaluation: impact assessment, priority setting, and resource allocation

In an era of increasingly scarce funds there is a need to show that it pays to invest in agricultural research. This has generated much interest and activity throughout the region in impact assessment. Although most studies have focused on ex-post analysis

14 Applying this approach to data covering 64 less-developed countries, Craig, Pardey, and Roseboom (1992) show that the discriminating power of these zones is far less dramatic in other parts of the world, particularly in Asia.

15 Although some proportion of the FAO zones covered cold or dry regions where agricultural production would not be viable.

of research investments, there is a growing realization that research evaluation should, and can, do more to support priority setting and resource allocation in an ex-ante framework.

In fact, the region has a relatively active history in all types of research evaluation, mostly at the single country, single commodity level. Research evaluation cum priority setting exercises using the scoring approach have been applied in the Dominican Republic (ISA 1986), Ecuador (Espinosa et al. 1986), and Uruguay (CIAAB 1987), usually in the context of ex-ante priority setting. More popular have been various forms of economic surplus studies, usually for *ex-post* impact assessment (Echeverría et al. 1988, Martinez and Sain 1983, Yrarrazaval et al. 1982). One such study of relevance to regional collaborative research was the multicommodity research impact assessment undertaken for PROCISUR (Evenson and Da Cruz 1989a). Other efforts have been more limited in scope, and most have neither multimarket, nor multizone disaggregations, although technology spillover was addressed in at least one study (Evenson and Da Cruz 1989b). CIAT has been a prime mover in the area of ex-ante analysis using economic surplus and comparative advantage formulations (Lynam and Jones 1984, Pachicho et al. 1987, Sere and Jarvis 1988, Velasquez et al. 1991) and, as discussed in section 4.1, have developed a spreadsheet based ex-ante economic surplus software package called MODEXC (Rivas et al. 1991). An ex-ante economic surplus model of the ACIAR (multimarket and zone) type has been used in Peru (Norton and Ganoza 1985 and 1986, and Norton, Ganoza, and Pomerada 1987), while a combined economic surplus-scoring method approach has recently been used in Ecuador (Palomino and Norton 1992). As part of its research evaluation strengthening, INTA is currently adapting the latest ISNAR implementation of multimarket evaluation models (Macagno 1992).

Regional research collaboration

Macalla (1991) justifies collaborative research in the following way:

> [W]e want to invest (in collaborative international research) because: (1) we consider it to be more efficient (to take advantage of economies of scale); (2) there is potential wide adaptability of the research product (varieties which perform well under a wide variety of conditions, e.g., dwarf wheat); (3) we expect the results of the research to have applications beyond the site on which it is done (spillover); or (4) because the speed and comprehensiveness of the research is enhanced by multi-locational opportunities (e.g., shuttle breeding, different pest and disease pressures–hot spots).

Although these comments were addressed to the CGIAR collaborative research effort, they are equally valid in the context of research collaboration in the LAC region.

Regional and subregional cooperation and collaboration in research gives every appearance of being active and relatively successful in LAC. Perhaps the prime examples are the PROCI groupings supported by IICA, but there are many others including

LAC networks on food crop-production systems (Red de Cooperación Técnica en Producción de Cultivos Alimenticios) and animal health and disease diagnosis (Red de Cooperación Técnica entre Laboratorios de Investigación y Diagnóstico Veterinario). On the agroecological side, there are also regional collaborative groups concerned with environmental sustainability, watershed management, acid soil management, and the Amazon Treaty's ambitious program of ecologic-economic zoning, which promises to deliver much valuable data for the entire Amazon basin over the next two to three years. Undoubtedly a significant contributing factor to this active collaboration is the high level of communication and interchange afforded by a common language (with the notable exceptions of Brazil and the British-speaking Caribbean). However, of primary concern is the extent to which the potential economies of scale and scope that collaboration can offer are actually being realized in practice.

There are many examples of regional collaborative research success, and we briefly mention two that appear to have provided significant benefits although, as far as is known, neither has been evaluated quantitatively. The first is a NARS-to-NARS success story of technology transfer facilitated by the PROCISUR germ plasm program LACOS (Lineas Avanzadas del Cono Sur) in which the Chilean wheat cultivar Millaleau-INIA was found to be significantly superior to local cultivars in Paraguay. Following the shipment of 180 tons of seed from Chile, the locally renamed Cordillera 3 cultivar was released in Paraguay and soon accounted for around 60% of the planted wheat area (Sergio Bonilla, personal communication). This is but one of several impacts briefly documented in the periodic reports of PROCISUR. The only known attempt to quantify the impact of the overall PROCISUR program was made by Evenson and Da Cruz (1989a). The second example is of an IARC-NARS collaboration in which CIMMYT and EMBRAPA embarked upon an ambitious program to improve wheat yields in the large, acid, savanna areas of Brazil where aluminum toxicity and phosphorus deficiency are major production constraints. The collaboration evolved a system of shuttle breeding between germ plasm pools in Mexico and Brazil. At the Mexican end were the high-yielding, semi-dwarf cultivars and in Brazil were the low-yielding but relatively aluminum tolerant lines. Scientists at both ends made crosses of the most promising lines, which were then sent to the partner for screening under local abiotic and disease pressures. Over the life of this program, breeders enhanced aluminum tolerance to the extent that yields increased a minimum of 25-30% in comparison with the best pre-existing varieties.

Above, four main areas were identified in which production-related research was focused: increased genetic potential, amelioration of abiotic environmental constraints, amelioration of biotic constraints, and improved production management. The cases just described are representative of the first two areas: the PROCISUR/LACOS program identified germ plasm with superior yield potential, whereas the CIMMYT/EMBRAPA collaboration was specifically targeted to ameliorating abiotic constraints. Examples of similar regional collaboration addressing biotic constraints can be seen in CIMMYT's disease-monitoring international nursery where more rapid screening and development of germ plasm is possible through access to a wider range of pest and disease hot spots. In a similar way, collaborative research on crop, land, and water management practices through various regional networks seeks to accelerate the identification and dissemination of appropriate technologies in these areas.

However, it is not only in production research programs that regional collaboration has been active. Regional collaboration in land resource assessment was discussed in above. Another important long-term goal is the strengthening of research planning and management in the region's NARSs. It is in this latter context that capacity building in the development of quantitative research evaluation is being proposed.

Issues from the Region

During the course of this review the goals and applications of research evaluation in the LAC setting were discussed with a large number of the individuals identified in Appendix 1. Many issues were raised, but several appeared to be of general concern and are drawn together here. It is important that these issues receive proper attention in formulating any subsequent proposals for action.

LAC research management as a multiactor endeavor

With the active participation of IICA and IARCs such as CIMMYT, CIAT, and CIP, regional and subregional groupings such as PROCISUR and PROCIANDINO, and the NARSs themselves (and with an apparently strong tradition of subnational autonomy over research planning and investment in many countries), there are many intricacies in the formulation of research strategy at any level in LAC.[16] A major question posed by several managers was the extent to which it is (a) desirable and (b) feasible to formulate a research priority setting and resource allocation decision support system that attempts to capture this real world complexity. Such a framework would need to handle multiple resource allocation layers and, correspondingly, multiple sets of objectives. On the other hand, a simple analytical framework could be developed that could be applied independently at each layer, assuming all other research allocations and impacts were exogenous. However, it is difficult to escape the conclusion that the facility must exist for evaluation on the basis of multiple decision and investment levels even for a single national research system. This is not a major methodological hurdle, and ongoing ISNAR research priority-setting projects, for example China and Argentina, are applying models in situations where there are multiple decision-making levels from a research evaluation perspective.

Trade

Trade is an important issue in LAC for practically all commodities. The ability of research evaluation to assist in exploring the potential trade impacts of research was questioned by several. In fact, this poses little problem to the proposed evaluation

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16 Even putting aside the important issue of private- versus public-sector research roles and responsibilities.

methodology, which is built around the concept of multiple markets. These markets can be individual LAC countries (or even subnational regions), but can also be important external trading partners, e.g., the USA and EEC.[17] Different expected research impacts across zones and regions gives rise to different market impacts and these, in turn, differentially effect relative market prices, production, and consumption levels. Trade could be defined as occurring within the LAC region only, or it could include external markets as required. Extensions to the basic model can also take into account various forms of taxes and/or subsidies on a region-by-region or country-by-country basis (Alston, Norton, and Pardey 1993). These other policy interventions can alter the size and, more significantly, the distribution of the benefits of research. For this reason, it is important to include them explicitly in a research evaluation exercise, especially where the distributional consequences of research (e.g., between different countries) has obvious policy ramifications.

Beyond the single commodity approach

The growing tendency to move away from single-commodity research programs toward, for example, agroecosystem programs has already been noted. Since agroecosystems often involve multiple products, it is feasible that research impacts would be observed simultaneously in several commodity markets. To estimate the likely levels of research impact on multiple product systems is complex both technically and economically because of cross-commodity effects. How will this type of research be properly analyzed in the single commodity, partial equilibrium, economic surplus model?

Likewise, research into natural resource assessment and agroecology, and many aspects of socioeconomics are all important agricultural research issues, but are often not commodity specific and raise their own set of evaluation challenges. How can this type of research be taken into account in a commodity-based assessment framework?

While these challenges are not new to research analysts, broadly acceptable quantitative methodologies to tackle them are only beginning to be developed. It is obviously desirable that the effects of all types of research activity be assessed within any regional analytical framework, and satisfactory procedures need to be developed to ensure that this is possible.

Sustainability

A frequently asked question was whether research evaluation could "handle" sustainability. As discussed briefly above, to the extent that sustainability concerns can be related to the potential environmental impacts of new technologies then an evaluation

17 Remembering that data of the type summarized in Table 2 must be provided for each defined region.

framework can indeed be useful. For example, the definition of agroecological zones can include criteria that are important from an environmental degradation perspective, for example soils of different slope, depth, and erodibility. Subsequently, technologies can be assessed not only for their productivity impacts but also in terms of their environmental impacts in each of the zones. The zones then provide a means of aggregating potential environmental impacts across all production areas. Given the many ways in which environment can be affected, this type of assessment would not be trivial, but the evaluation framework would provide a means by which some measure of research impact on degradation could be generated alongside more traditional and narrowly defined measures of productivity gain.

Maintenance research

There was much awareness that a seemingly growing proportion of research expenditure involves maintenance research (e.g., research to counter the breakdown in resistance of existing varieties to pest and disease), and questions were raised about whether research evaluation would be able to analyze maintenance research efforts. It was hoped that evaluation would allow research managers to demonstrate, particularly to funding agencies, the ongoing need for, and benefits of, maintenance research.

If impact assessment is made on the basis of comparing two production alternatives, one *without* new technologies and one *with* new technologies, then maintenance research effects would be taken into account. If, without new technologies, scientists expect yields to breakdown by 5% over the next five years but, with new technologies, that breakdown will be only 1%, then research (including maintenance research) will have provided a gain (avoided loss) of 4%–on which basis the benefit of the research can be assessed.

Flexibility in spatial decision units

Some LAC countries are very small, while others are extremely large. While there will always be a need to produce results on a national basis, it may also be desirable and necessary to undertake an analysis at the subnational level. The hope was expressed that the evaluation methodology would contain the flexibility for users to select the spatial unit most relevant to their analysis. Subject to the availability of suitably disaggregated data, this would indeed be the case.

Implementation Options

Investment in improved quantitative support to LAC agricultural research decision making appears timely from perspectives of relevance, feasibility, and probability of success. The growing complexity of research policy formulation, coupled with ever-tightening budget constraints, demand improved decision aids to monitor, evaluate, and plan research investments. However, in a region as diverse as LAC care must be taken to develop approaches with sufficient institutional and technical resilience–it is unlikely that any one approach will be universally applicable. A stylized representation of the type of overall framework envisaged is presented in Figure 5. Below is a set of ideas for moving forward with the implementation of this type of analytical framework.

Identification of the client group

There appear to be at least three client groups for improved research evaluation information:

NARSs improving the effectiveness of national research by identifying and prioritizing investments likely to maximize targeted impacts. Better understanding of the potential advantages and disadvantages that may arise from transnational research collaboration.

IARCs planning interventions in their own fields of comparative advantage in collaboration with, or complementary to, the work of NARSs.

Funders identifying research investment needs or opportunities in locations and in programs that address the concerns of the funding agencies, be they local sources of support or the international donor community.

Specification of the primary products and services

There appears to be a need for two (phased) parallel streams of products and services, one at a regional level and the other at national level.

Regional level. An evaluation capacity needs to be developed around a regionally comprehensive but relatively aggregate research evaluation database linked to a limited range of evaluation models.[18] The minimum database requirement covers agroecological zoning criteria in digital map form with supplemental data on, say, land status and accessibility; market information including production, consumption, import, export quantity and related price data; elasticities for all major agricultural commodities, demographic and income trends; and research system time series of personnel, expenditure and other indicators of research capacity. In terms of evaluation methods and applications, it is probably most appropriate to focus on ex-ante research assessments to support regional policy analysis and priority setting. At this level the regional model would provide an interface with IARCs and the funding community. A major area of interest would

18 The data would be held aggregated to country level except for larger countries, for example Brazil and Argentina, where subnational units would need to be utilized.

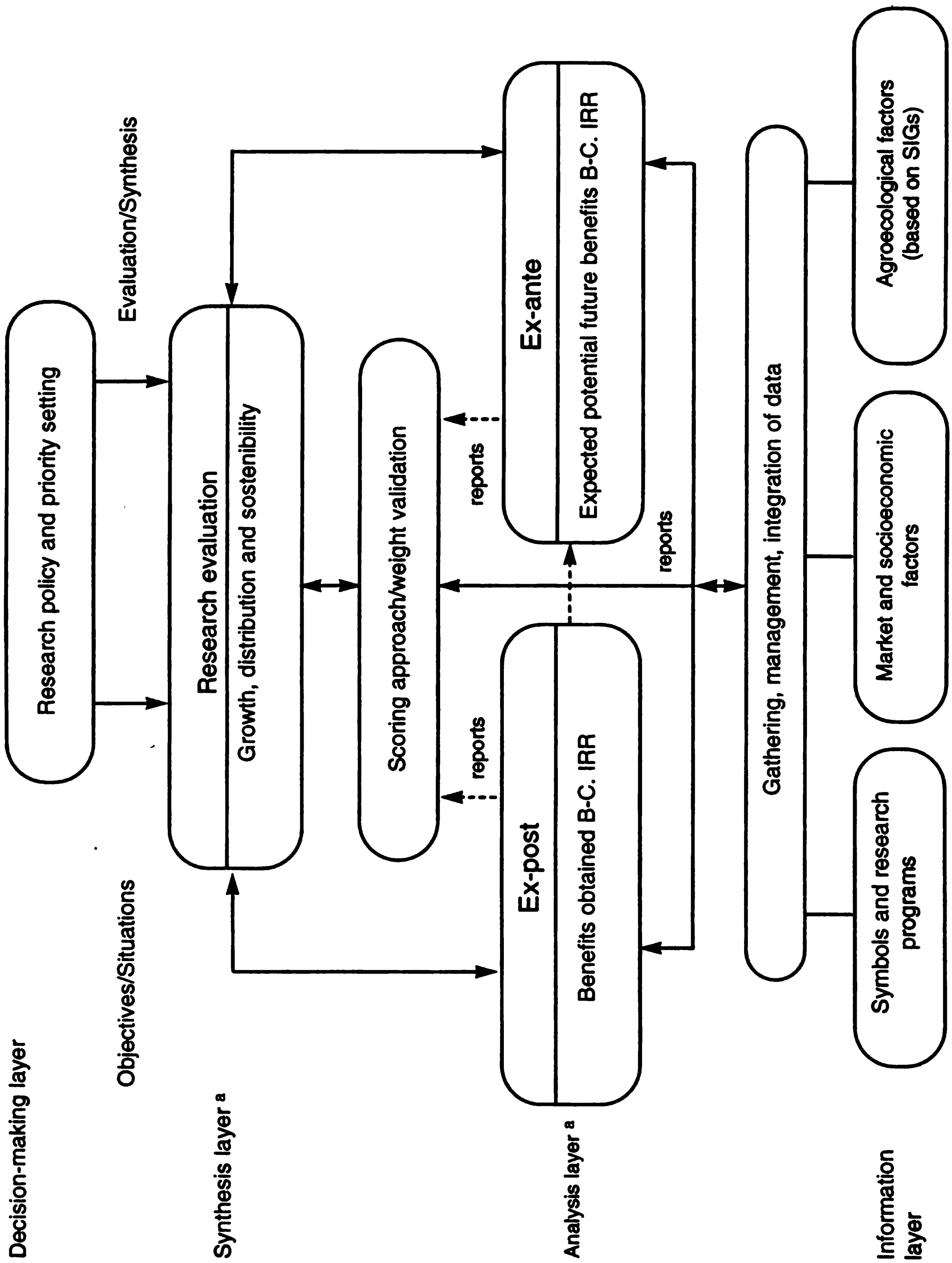

Figure 5. A stylized framework for regional and national research evaluation.

a The analysis and synthesis layers must be capable of addressing issues of multiple regions, trade (multiple markets), multiple agroecological zones, and multiple decision-making layers.

be in identifying specific economies of scale, economies of scope and patterns of comparative advantage that would suggest the opportunity for various types of bilateral and regional research initiatives to complement those at the national level.

National level. Individual countries would have the responsibility to establish their own research evaluation cells but could all take the regional evaluation system as a starting point and expand the specification of their individual countries as required. Given the potentially large number of countries involved there is an obvious need to establish some form of phased implementation support. At this level, the range of analysis options would need to be broader, including ex-post impact monitoring and evaluation studies in addition to ex-ante analysis for priority setting and resource allocation. A two-way exchange of information with the regional level could be envisaged in which the national level provided periodically updated aggregate data in exchange for updated aggregates from other countries in the region. Even at the national level, each country needs aggregate statistics from other countries in order to investigate research spillover and trade issues.

Organizational and institutional responsibilities

IICA provides a clear institutional lead agency in terms of mandate and experience, as well as its strong linkages to NARSs both through its subregional PROCI groupings and direct contact. Whether IICA has the wish or capacity to house the regional evaluation unit and some regional support capacity for national-level implementation would need to be established. The involvement of IARCs, primarily the regional CGIAR centers, would be important both technically and institutionally, and probably could be achieved on the basis of representation on a standing technical committee and/or by contractual, technical backstopping services. One speculative allocation of such backstopping tasks, coinciding with the major data groupings, could be CIAT–agroecology, IFPRI (International Food Policy Institute) and CIMMYT–policy and economics, and ISNAR–research systems. At the national level, NARSs, themselves, would be responsible for implementing and managing local research evaluation tasks, assisted, to the extent possible, by these various support services.

Training and manpower development

Quantified research evaluation requires specialist skills. Successful development of an in-house capacity calls for a serious and probably sustained training effort at both the decision-making and analyst level. Research managers, and decision makers in general, need to be informed of the type of information that could be made available to them and how that could help in making better decisions. Analysts need to be trained in the skills of scenario formulation, analysis, interpretation and presentation of results in ways that are timely, accurate, and as relevant as possible. This implies a major effort in the development of appropriate training materials in addition to delivery of training courses.

Activity plan

To explore the modalities of implementation and to allow a chance to better gauge patterns of interest and need at the national level, the following activities could be conceived:

Regional pilot study (24-30 months)

A regional research evaluation unit would be established to

- establish regional aggregate databases; agroecology,[19] market-related data, and research-related data
- evaluate and modify as appropriate existing ex-ante economic surplus model formulations
- integrate database and analysis systems
- formulate, investigate, and report upon an illustrative set of regional research policy issues

For a limited range of commodities an illustrative set of policy scenarios could be explored. These would serve not only to test the initial adequacy of the database and evaluation methodology, but would serve to demonstrate to funders and NARSs the general capabilities and limitations of the quantitative approach, in addition to generating valuable training material. At least two of the obvious candidate commodities would be wheat and rice. They have regional importance, provide good agroecological complements, are well documented, and could test the modalities of relationships with key regional CG centers in this type of activity.

Preparation for national implementation (12-18 months)

- This phase (partially overlapping with the pilot regional study) would finalize the methods, procedures, and software aids necessary to commence implementation at the national level. A key element would be the preparation of documentation and training materials to support a comprehensive program of training.

The national implementation phase (3-5 years)

- Would focus simply on the transfer and evolution of research evaluation technologies based on the regional system, and on institutional guidance on the integration of research evaluation into the broader responsibilities of research management.

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19 As a contribution to this early work on the establishment of an agroecological framework for research evaluation, the associated volume Digital Map Inventory of Latin America (Wood and Panghudi 1993) has been prepared.

FINAL COMMENTS

By the mid-1980s, the latest year comparable figures are available, public agricultural research systems in the LAC region employed a total of 9000 researchers and spent over US$700 million (1980) annually. As government budgets tighten generally, there is mounting pressure for these research agencies to be more accountable for their use of public resources. And accountability, regardless of the source of funds,[20] increasingly calls for a clear demonstration that the likely economic returns from research remain attractive. While the international donor and lending community is making similar demands for accountability, for them the potential returns to research at the regional and subregional level are often as much of a concern as are the payoffs to research for any particular country.

Many of these investment decisions–including how much to commit and to whom, what types of research to support, and who should pay for what–are currently being made with little reference to any systematic evaluation of the expected economic effects of research. The size and, particularly, the distribution of research benefits, whether between social groups (e.g., urban consumers or low-income farmers) within a country, or between countries themselves, are directly influenced by a host of government programs that ultimately tax or subsidize the agricultural sector. So, in order to gain an appreciation of the ultimate growth, equity, and environmental consequences of research, it is not enough to study only its technological impact. This is particularly so in the LAC region where there are widespread attempts to reduce government intervention in domestic markets and pursue more outward-oriented economic policies. These changes could radically alter the pattern of agricultural production and trade throughout the region and with it, the demand for, and effects of, new agricultural technologies and know-how.

An improved understanding of the likely economic effects of research would help to inform research priority setting at the regional and national levels. This report deals with the potential for incorporating agroecological considerations into an ex-ante research evaluation framework designed to do just that. As we have described, agroecological analysis, and the relatively cost-effective GIS procedures that are now the established tools of the trade, can help to develop plausible estimates of the local and spillover effects of agricultural research at the spatial scales needed for working at national and regional levels. In this way, the informed estimates of scientists and others about the productivity and environmental consequences of agricultural research can be integrated with market-related data to obtain national and continent-wide estimates of the size and incidence of the economic effects of research.

The analytical methods reviewed in this report in no way substitute for the best judgments of scientists and policymakers in the research priority setting process. What they

20 Be they government, semipublic, or private.

do is provide a unifying framework within which to synthesize a wide range of scientific and economic data, be they quantitative or qualitative, which would otherwise be difficult to reconcile and use. Thus, good judgment can be made even better and poor judgements may be revealed for what they are. These procedures also enable the disparate productivity and environmental consequences of research to be reported using a comparable money measure. By so doing they can reveal research opportunities and consequences that at first sight may not be obvious. The potential for research results to spill across national boundaries because of agroecological similarities may point to possible gains from cross-country collaboration in research. There again, government policies (e.g., quarantine regulations, trade restrictions, and so on) and institutional constraints may limit the trade in technologies that is needed to realize these spillover potentials. The systematic approach described in this report pays due regard to these broader economic factors without abandoning the scientific basis of research evaluation. Striking a balance between these economic and scientific aspects is essential if notions of regional cooperation in agricultural research are not to founder on the political and institutional realities within which they must be implemented.

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APPENDIX 1

Institutions and Persons Contacted

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Juan A. Nocetti	Director of Planning
Luis Macagno	Director, Operational Planning and Resource Allocation
Carlos Scoppa	Director, Natural Resources Research Center
Cesar Rebella	Director, Institute of Climate and Water, CIREN
Dr. Musto	Senior Soil Scientist, CIREN
Gustavo Moscatelli	Senior Soil Scientist, CIREN
Gustavo Maccarini	Senior Soil Scientist and GIS Specialist, CIREN

CHILE

FAO Regional Office for Latin America and the Caribbean

Mathias Prieto Celi	Regional Soils and Water Officer
Walter Couto	AEZ—Soils Specialist

INIA

Sergio Bonilla Espindola	Foreign Affairs Coordinator

CIREN

Jose Antonio Bustamante	Deputy Director General

COLOMBIA

CIAT

Gustavo Nores	Director General
Filemon Torres	Deputy Director General
Gerardo E. Haebich	Associate Director, Institutional Relations
Peter Jones	Leader, Agroecological Studies Unit
Dan Robinson	Forest Margins Program
Cesar Martinez	Acting Leader and Rice Breeder, Rice Program
Almiro Ramirez Suarez	Economist, Rice Program
Robin H. Ruggles	Project Design Officer

Instituto Geografico "Agustin Codazzi", Bogota

Dimas Malagon Castro	Agroecological Deputy Director General

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Armando Vallejo Espinel	Technical Coordinator
Roberto Damanez	Chief Technical Advisor, FAO

PRONAREG

Enrique Suarez	Executive Director
Guillermo del Posso	Project Leader MAG-FAO/ECU/0051

MEXICO

CIMMYT

Gregorio Martinez Valdes	Head, Government and Public Affairs
Paul Fox	Head, International Wheat Testing
Edith Hesse de Polanco	Head, Scientific Information Unit
John Corbett	Associate Scientist, Rockefeller Fellow, GIS Unit
Miguel A. Lopez	Economist

ITALIA

FAO

Robert Brinkman	Chief, Soil Service (AGLS), AGL
Jose Benites	Technical Official, AGLS
Marina Zanetti	GIS Analyst, GIS Unit
D. Courteille D'Andrea	Librarian, AGL

HOLANDA

ISNAR

Christian Bonte-Friedheim	Director General
Howard Elliot	Deputy Director General

APPENDIX 2

FAO's LAC Regional Workshop on Agroecological Zones Methodology and Applications"

During Stanley Wood's period in South America (August-September 1992) he was invited to participate in a guest lecturer capacity at the FAO Regional Workshop held in Santiago. In addition to delivering three lectures, on a) AEZ conceptual framework, b) land use classification and AEZ analysis, and c) AEZ applications, discussions were held with individual country participants on the current status of, and approaches to, agroecological zoning and analysis in their respective countries. During the course of the workshop discussions were held with the following participants and fellow presenters:

Argentina	Gustavo Maccarini, Research Specialist, INTA-CIRN Soil Institute.
Bolivia	Milton Ruiz Barea, Irrigation and Soil Conservation Projects, Regional Development Corporation of Tarija (CODETAR).
	J. Oscar Siles Salas, Photo-interpreter/Remote Sensing, Environmental Impact Studies and Natural Resources.
Brazil	Fernando Barreto Rodrigues, Head, National Surveying and Soil Conservation Service, EMBRAPA.
	Alexandre Grimaldi de Castro, Associate Researcher, National Space Research Institute.
Chile	Horacio A. Merlet Badilla, Head, Climate Unit, Natural Resources Information Center (CIREN).
	Dominique Saintraint, GIS expert, FAO-GCP/RLA/107/JPN.
	Ricardo Honorato Pinto, Professor specializing in soils, Faculty of Agronomy, Pontificia Universidad Catolica de Chile.
	Matias Prieto-Celi, Regional Land and Water Development Officer, FAO Regional Office for Latin America and the Caribbean.
Colombia	Pedro Rubio Rivas, Head, Classification and Correlation Section, Agrological Subdirectorate, Agustin Codazzi Geographical Institute.
Costa Rica	Luis Alberto Arroyo Morales, Phytotechny Specialist, MAG Land Use Planning Directorate.
	Gilberto Palacio Alvarez, Soil Erosion Researcher, Universidad Nacional, Heredia.

Cuba	Francisco J. Arcia Porrua, Assistant Researcher and Head, Soils Section, National Sugarcane Research Institute.
Dom. Rep.	Tomas Montilla, Cartographer, Division Head, Agriculture Secretariat.
Ecuador	Guillermo del Posso Moncayo, Head, Technical Coordinator MAG-FAO/ECU/0051 Project, Natural Resources Studies Division, PRONAREG-MAG.
	Armando Vallejo Espinel, Technical Coordinator, Amazon Cooperation Treaty.
El Salvador	Ramon Garcia Vasquez, Head, Project Division, Subdirectorate for Irrigation and Drainage, General Directorate of Natural Resources, Ministry of Agriculture and Livestock.
Guatemala	Carlos Fernandez Rivera, UNDP-DIRYA Consultant, National Irrigation Plan.
	Carlos Orozco Ovando, Regional Planning Consultant, Research and Social Studies Association (ASIES).
Honduras	Candido Alberto Ruiz, LUPE Project, Forest Specialist, Ministry of Natural Resources recommended to USAID Office.
	Mario Roberto Nuñez, Agronomist, LUPE Project.
Indonesia	Ulrike Wood-Sichra, Advisor, FAO.
Italy	Jacques Antoine, Technical Officer, AGLS, FAO.
	Jose Benites, Technical Officer, AGLS, FAO.
Mexico	Eduardo Garcia Cardona, Biologist, Section Head, INEGI-General Directorate of Geography.
Nicaragua	Luis Herrera Gadea, Agronomist, Head, Forest Resources Evaluation Dept., Nicaraguan Institute for Natural Resources and the Environment (IRENA).
Paraguay	Lorenzo Alfonso Ortiz, Natural Resources Planning and Management Project, Ministry of Agriculture and Livestock.
	Miguel A. K. Moriya Roa, Head, Natural Resources Division, Technical Assistance, SEAG-MAG.

Peru	Jorge Ordoñez, H., Director, National Cadastre Program, PRONAC, Ministry of Agriculture.
	Cesar Cervantes Galvez, Director General, Integrated Studies on Natural Resources, National Office for Natural Resource Evaluation (ONERN).
Uruguay	Walter Couto, Advisor, FAO.
Venezuela	Mireya Mireles, Researcher II, National Agricultural Research Fund (FONAIAP), National Agricultural Research Center (CENIAP), IIAG, Land Evaluation Dept.

Chapter 3

SETTING PRIORITIES FOR AGRICULTURAL RESEARCH: A PROPOSAL TO ADAPT THE TAC* MODEL FOR LATIN AMERICA AND THE CARIBBEAN

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CONTENTS

SUMMARY

IICA and the IDB (Inter-American Development Bank) have combined efforts in a program entitled Priorities and Mechanisms for Coordinating and Managing Projects on Agricultural Research and Technology Development at the Regional Level (Agreement IICA/IDB, Technical Cooperation ANT/SF-3410-RE[4]). One of the objectives of this program is to "design an operating mechanism for identifying priorities and conducting coordination and management of agricultural research and technology development projects at the regional level."

The program held its first two working meetings in November 1992 in Bogota, Colombia, sessions that were attended by directors of research institutions in Latin America and the Caribbean (LAC) and experts in planning, evaluation, and priority-setting for agricultural research. The participants asked a group of specialists to review the report that the Technical Advisory Committee (TAC) had prepared for the Consultative Group on International Agricultural Research (CGIAR) and adapt it for use in LAC.

This document reviews the TAC method, drawing attention to certain drawbacks. Due to its limitations (hard to understand, insufficient information and time available), the original model is adapted only partially. The exercise preserves the same agroecological zones and offers a simple-to-understand method that will encourage greater participation by decision makers.

The paper contains an important innovation based on clear concerns expressed by decision makers. The idea is to have a methodological tool that incorporates new trade opportunities and greater market demand for traditional and new products.

The last chapter points out certain limitations of the proposal and suggests possible revisions of the indicators and methods being used.

INTRODUCTION

General Objectives of the Program

– Design a working mechanism to identify priorities and provide coordination and management of agricultural research and technology development projects throughout the region, so that the different parties involved can exchange experiences and more easily develop concrete proposals in areas of shared interest, thus making better use of available resources.

– Develop guidelines for boosting investments in agricultural research and technology development, in response to the processes of economic opening and liberalization and the new interest in natural resources, agriculture, and sustainable development.

– Design mechanisms to help national agricultural research and technology transfer systems orchestrate their work with the international centers of the CGIAR, in coordination with other donor agencies, based on the region's own particular priorities for agricultural research and technology development.

Specific Objective

To design tools by which the national agricultural research systems of LAC can more efficiently allocate resources available through donors, including the IDB and the World Bank.

The group of specialists that met in Buenos Aires produced a number of tools to help meet this specific objective.

THE TAC MODEL FOR LATIN AMERICA AND THE CARIBBEAN

This chapter describes the methods outlined by the TAC (originally applied to the entire developing world) in its model for setting priorities among agroecological zones (AEZs) and commodities in LAC. It also looks into certain assumptions, limitations and implications of the model.

Review of the Model

The TAC model[1] singles out three sectors: agriculture, forestry, and fisheries. Nine AEZs previously defined for LAC are ranked by priority for each of these three production sectors (see Appendix A):

AEZ1 - WARM ARID TROPICS AND SEMI-ARID TROPICS. Antigua, Suriname, Haiti, parts of Bolivia, Brazil, Cuba, Ecuador, Mexico and Venezuela.

AEZ2 - WARM SUBHUMID TROPICS. Bahamas, Dominican Republic, Guadeloupe, Martinique, St. Lucia, and parts of Bolivia, Brazil, Costa Rica, Cuba, Ecuador, El Salvador, Mexico, Paraguay and Venezuela.

AEZ3 - WARM HUMID TROPICS. Barbados, Belize, French Guiana, Guyana, Jamaica, Nicaragua, Panama, Puerto Rico, Suriname, Trinidad and Tobago, Windward Isles, and parts of Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Peru and Venezuela.

AEZ4 - COOL TROPICS. Parts of Bolivia, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico and Peru.

AEZ5 - WARM ARID AND SEMI-ARID SUBTROPICS WITH SUMMER RAINFALL. Parts of Argentina and Mexico.

AEZ6 - WARM SUBHUMID SUBTROPICS WITH SUMMER RAINFALL. Parts of Argentina.

AEZ7 - WARM/COOL HUMID SUBTROPICS WITH SUMMER RAINFALL. Parts of Argentina, Brazil and Paraguay.

AEZ8 - COOL SUBTROPICS WITH SUMMER RAINFALL. Uruguay and parts of Argentina.

AEZ9 - COOL SUBTROPICS WITH WINTER RAINFALL. Chile and parts of Argentina.

The model is then used to determine priorities for different lines of agricultural and forestry production. For the case of LAC, the data given in the TAC and CGIAR document (1992) rank only agriculture and forestry.

The first stage was to produce a basic priority rating for the nine AEZs, using the congruence approach with three fundamental objectives (criteria): efficiency, equity, and sustainability. Three "representative" indicators were selected for this purpose: value of production, number of poor, and number of hectares in use. The model assigns a score in

1 TAC model as described in the TAC CGIAR document Review of CGIAR Priorities and Strategies FAO, April 1992 (AGR/TAC/92/18).

direct proportion to the value of these variables, using the same scale. The assumption is that research yields the same returns in each AEZ, and this return rises in regions that post higher values of production, greater numbers of poor, or more land in use. This gives a first bias for setting higher priority on regions with large countries.

For each of the three variables, this model normalizes data from the AEZs to add up to 1000. The point values for each AEZ are then multiplied by a weight for each variable, giving a weighted average for each AEZ, called the **baseline value**, that can be used to set an initial priority ranking. Table 1 gives initial priority rankings with weights for the agricultural sector. Appendix C (Table 1) gives the information for the forestry sector.

Once this initial priority ranking is complete, a second step is to define modifiers for certain objectives to be used in adjusting the scores given in the congruence model. Below are descriptions of the TAC modifiers for each AEZ, along with the direction of their impact.

Modifier	Associated Objective	Direction of Modifier
a. Gap in yields	Efficiency	It is assumed that as the gap narrows, greater efforts are required in strategic research (-)
b. Level of malnutrition	Equity	As malnutrition increases, the priority increases (+)
c. Per capita GDP	Equity	As per capita GDP decreases, the priority increases (-)
d. Food "urgency" or pressure	Sustainability	As the urgency grows, greater is pressure the need for growth and the priority increases (+)
e. Deforestation	Sustainability	The priority increases as deforestation increases (+)
f. Risk of soil degradation	Sustainability	As the risk increases, the priority increases (+)
g. Capacity of national research systems	Institutional strength	The greater the capacity, less priority is assigned (-)
h. Size of country	Institutional strength	As the average country size increases, the priority decreases (-)
i. Gap in food imports	Capacity for supply	As the gap widens, the priority increases (+)
j. Area of forest per capita	Preservation of forest resources	More weight is assigned to AEZ's whose forested surface area per capita is low (-)

The modifications described are used to change the basic values presented in Table 1.

Table 1 shows baseline values from each agroecological zone. The purpose of the model is to adjust these values by applying the different modifiers given above.

Table 1. Baseline values for setting agricultural priorities by agroecological zone (x 000).

AEZ	Value of production (VOP)	No. of poor	Usable land	Baseline value
Weights	0.333	0.333	0.333	
1	73.4	82.4	78.7	78.1
2	198.3	144.9	221.0	187.9
3	181.8	196.7	304.4	227.4
4	128.2	321.9	119.7	189.7
5	50.0	29.2	34.6	37.9
6	28.3	7.6	18.3	18.0
7	195.9	129.4	102.4	142.4
8	115.0	53.5	93.2	87.1
9	29.1	34.4	27.9	30.5
	1000.0	1000.0	1000.0	1000.0

Source: Prepared by the authors based on TAC/CGIAR 1992.

Table 2 shows how to calculate the effect of the "yield gap" modifier, to give adjusted baseline values. The first step is to normalize the value of the modifier to base 1 (see line 3 of Table 2, with the AEZ6 figure as base 1). If the modifier has a negative direction (-), it then needs to be reversed by subtracting the normalized value from one (line 4). Multiply this by a weight, which in the example is 0.5 (line 5). The baseline value (line 1) is then multiplied by these weighted modifiers (line 6), so that each one is affected proportionally. Divide this product by 1000 and multiply by the baseline value (line 1), so they will all be modified in the same proportion (line 7). Make sure the figures for all the AEZs add up to the same total as the figure in line 6. The point score for each zone is then redistributed, subtracting the values in line 7 from those in line 6, so they add up to zero (line 8). Finally, add line 8 to the original baseline value (line 1), giving the adjusted baseline value.

Several different procedures can be used for normalizing the values of the modifier (lines 3 and 4). The TAC uses a linear method, while IFPRI suggests an exponential approach. However, it is not critical to select one particular method over another because the effect of the modifier, as for example in redistributing points across zones, can be controlled by selecting an appropriate weight.

Table 2. Example: Baseline value adjusted by yield gap modifier.

	Agroecological zones in LAC									
	1	2	3	4	5	6	7	8	9	TOTAL
1. Baseline value	78.10	187.90	227.90	189.70	37.90	18.10	142.50	87.20	30.70	1000.00
2. Yield gap	0.61	0.84	0.77	0.53	0.84	0.90	0.82	0.86	0.82	
3. Normalize to 1	0.68	0.93	0.86	0.59	0.93	1.00	0.91	0.96	0.91	
4. Change direction (1 - line 3)	0.32	0.07	0.14	0.41	0.07	0.00	0.09	0.04	0.09	
5. Weigh (line 4 _ 0.5)	0.16	0.03	0.07	0.21	0.03	0.00	0.04	0.02	0.04	85.20
6. Line 5 _ line 1	12.58	6.26	16.46	38.99	1.26	0.00	6.33	1.94	1.36	85.20
7. Line 1 _ line 6/1000	6.65	16.01	19.42	16.16	3.23	1.54	12.14	7.43	2.62	0.00
8. Net change (line 6 - line 7)	5.93	9.75	-2.96	22.83	-1.97	-1.54	-5.81	-5.49	-1.25	1000.00
9. New value (line 1 + line 8)	84.03	178.15	224.94	212.53	35.93	16.56	136.69	81.71	29.45	

Source: Prepared by authors based on Table 1 and TAC/CGIAR 1992.

Table 3 shows how the baseline values change with the application of each modifier in each region. The penultimate column gives the adjusted baseline value for each AEZ, reflecting addition or subtraction of all the net changes. The final column shows percent changes in baseline value for each AEZ. The relative priorities of the AEZs shift when the effects of all the modifiers are considered simultaneously. For example, while AEZ 4 was originally in second place, it drops to third priority when the effect of all the modifiers is included.

This procedure was also applied to LAC for the forestry sector, with modifiers for which information was available (yield gap, per capita GDP, urgency, soil degradation, capacity of NARIs, size of country). The results are given in Appendix C (Tables 1 and 2).

Table 3. Quantitative impact of modifiers on agriculture, with a weight of 0.5.

AEZ zone	Baseline value	Yield gap	Per-capita GDP	Urgency	Soil degradation	NARIs capacity	Country size	New baseline	% change
1	78.10	5.93	0.33	4.54	-2.96	12.58	-22.10	76.36	-0.02
2	187.90	-9.75	-5.87	-9.53	11.31	-4.06	26.19	196.59	0.05
3	227.90	-2.96	6.93	-2.11	52.72	-6.46	22.91	298.52	0.31
4	189.70	22.83	15.57	17.41	-13.00	5.92	-53.70	184.71	-0.03
5	37.90	-1.97	-0.94	5.15	-3.55	7.75	4.02	48.44	0.28
6	18.10	-1.54	-2.00	-3.50	-0.60	4.42	2.91	17.83	-0.01
7	142.50	-5.81	-5.84	-4.64	-24.90	-7.31	7.20	101.34	-0.29
8	87.20	-5.49	-9.15	-13.23	-15.10	-19.69	9.27	33.65	-0.61
9	30.70	-1.25	0.98	5.92	-3.90	6.84	3.25	42.59	0.39
	1000.00	0.0	0.0	0.0	0.0	0.0	0.0	1000.0	0.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

Now that the priorities have been rescored for each AEZ, commodities can be individually ranked for the different zones. The first step is to complete Table 4. The figures on value of production given in Table 1 are copied onto column 1 of Table 4. Column 2 shows the final score for each agroecological zone, copied from Table 3 (penultimate column). This figure is then divided by the figure in column 1, and the result given in column 3. This tells the relative importance of each AEZ. If the index is greater than one, it means that the AEZ's priority is greater as modified than it was given the simple value of production (as in the case of AEZ 3).

Table 4. Priority index of agroecological zones for the agricultural sector.

AEZ	Value of production (1)	Priority (2)	Index (2)/(1)
1	73.4	76.36	1.040347
2	198.3	196.60	0.991427
3	181.8	298.50	1.641914
4	128.2	184.60	1.439938
5	50.8	48.44	0.953543
6	28.3	17.83	0.630035
7	195.9	101.50	0.518121
8	115.0	33.65	0.292609
9	29.1	42.52	1.461168

Source: Tables 1 and 3.

Now commodities can be listed by value of production for the agricultural sector, and then priority ranked according to their weighted value of production in each AEZ. For this purpose, the index calculated in Table 4 is multiplied by the value of the commodity in each AEZ. This raises the relative importance of production lines in high-priority AEZs, and lessens the priority for lower ranked zones.

Table 5 shows modified production values for each production line in each AEZ. These are summed to give total adjusted production value for the entire region. This adjusted regional total is then used as a basis for normalizing the production of each commodity by AEZ to base 100, so that the AEZs can be priority ranked for each production line. Column 2 of Table 5 also shows percent distributions of each commodity for the whole region. Priorities for each production line for LAC as a whole emerge clearly. A similar procedure was followed to determine priorities for the forestry sector, and the information can be found in Appendix C.

Limitations of the Model

It is important to understand why the TAC called for a priority-setting model to be developed. The objective was to contribute to the CGIAR's task of allocating resources among regions, AEZs, production categories, and commodities, eventually also reaching the level of individual activities (natural resources, germ plasm, and the like).

Table 5. Percent distribution of gross value of production, adjusted by priority of AEZs.

Commodity	VOP	VDP Adjust	Agroecological zones 1	2	3	4	5	6	7	8	9	Total
Rice	3.29	3.51	9.23	20.26	44.70	7.09	1.14	0.20	14.81	2.07	0.50	100
Wheat	2.91	2.12	4.67	0.00	0.00	17.35	14.29	5.51	25.20	25.59	7.39	100
Maize	5.10	4.99	7.63	18.42	25.30	18.32	6.69	1.40	15.04	6.19	1.01	100
Barley	0.18	0.17	0.00	0.00	0.84	52.11	16.74	2.10	8.54	16.46	3.20	100
Sorghum	0.91	0.91	12.74	15.94	1.95	36.86	18.69	2.30	0.74	10.54	0.25	100
Millet	0.01	0.01	0.00	0.00	0.00	0.00	12.09	14.98	4.99	65.93	2.00	100
Cassava	1.84	2.08	10.44	34.86	47.85	0.00	0.11	0.14	6.60	0.00	0.01	100
Potato	2.00	2.05	4.40	1.16	0.64	65.19	4.38	1.92	8.98	8.98	4.35	100
Sweet potato	0.24	0.22	28.38	18.37	15.04	8.48	6.00	6.64	14.49	1.70	0.89	100
Yam	0.07	0.09	13.37	18.31	68.32	0.00	0.00	0.00	0.00	0.00	0.00	100
Banana, plantain	3.37	4.00	12.21	17.31	39.93	21.96	2.09	0.26	6.21	0.00	0.03	100
Chick-pea	0.05	0.06	8.94	10.42	22.86	34.33	19.63	0.19	0.09	0.75	2.80	100
Cowpea	0.02	0.02	96.14	0.00	3.86	0.00	0.00	0.00	0.00	0.00	0.00	100
Pigeon pea	0.01	0.02	13.55	54.36	32.09	0.00	0.00	0.00	0.00	0.00	0.00	100
Broad bean	0.08	0.09	6.02	17.78	17.10	39.57	6.90	0.55	9.36	2.67	0.06	100
Lentil	0.03	0.03	3.77	3.92	14.07	29.89	10.37	3.53	1.04	15.15	18.27	100
Beans	2.42	2.45	8.52	20.81	27.77	17.84	5.60	0.40	15.97	1.79	1.29	100
Soybean	7.29	6.19	6.23	22.09	27.05	0.15	3.19	2.92	25.14	12.91	0.32	100
Groundnut	0.44	0.37	19.38	29.23	3.08	1.14	19.25	21.74	3.77	0.09	2.32	100
Coconut	0.35	0.40	12.08	22.79	46.41	0.00	12.99	0.00	5.73	0.00	0.00	100
Tomato	1.22	1.23	9.19	18.05	24.17	21.39	7.91	0.97	9.73	4.83	3.75	100
Onion	0.50	0.50	4.42	12.38	24.57	30.10	1.26	1.65	10.88	7.75	7.00	100
Cabbage	0.10	0.12	6.63	6.04	29.64	51.58	3.85	0.00	0.00	0.13	2.14	100
Orange	9.81	9.80	3.58	31.60	37.74	3.90	2.23	0.33	18.71	1.69	0.22	100
Lemon & lime	1.44	1.42	6.97	18.89	29.95	12.08	9.26	2.50	6.08	12.44	1.83	100
Pineapple	0.59	0.70	3.14	21.26	45.55	17.78	3.03	0.06	9.18	0.00	0.00	100
Grape	4.18	3.01	1.98	8.81	13.17	3.82	3.55	8.42	6.76	38.52	14.97	100
Apple	0.92	0.73	0.00	0.00	0.00	41.00	0.00	4.92	13.61	22.49	17.98	100
Sugarcane	5.52	5.84	20.85	25.75	37.22	0.00	5.68	1.15	8.25	0.17	0.93	100
Coffee	7.57	8.86	0.00	17.96	31.46	39.31	0.00	0.00	11.28	0.00	0.00	100
Tea	0.09	0.07	0.00	8.39	12.45	16.92	0.00	9.63	10.51	42.11	0.00	100
Cocoa	0.98	1.25	0.00	36.54	63.42	0.04	0.00	0.00	0.00	0.00	0.00	100
Tobacco	1.69	1.64	9.98	25.51	36.38	0.00	5.64	3.29	17.90	0.12	1.18	100
Rubber	0.05	0.06	1.37	16.81	67.92	0.00	0.00	0.00	13.91	0.00	0.00	100
Cotton	1.83	1.88	11.40	36.30	32.44	0.14	8.81	4.41	6.03	0.00	0.47	100
Jute	0.01	0.01	0.00	23.91	52.79	0.00	0.00	0.00	23.30	0.00	0.00	100
Hemp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100
Sisal	0.11	0.10	24.32	66.14	0.14	0.00	9.39	0.00	0.00	0.00	0.00	100
Palm oil	0.18	0.27	0.24	8.12	91.55	0.00	0.09	0.00	0.00	0.00	0.00	100
Beef	12.64	11.99	7.37	13.80	22.65	20.45	7.29	2.85	9.37	14.54	1.67	100
Sheep, goat meat	0.61	0.57	7.67	9.79	17.73	27.24	6.12	2.43	5.94	19.77	3.31	100
Pig meat	2.32	2.54	7.43	13.20	26.03	34.66	3.48	0.43	9.47	3.21	2.09	100
Poultry	3.08	3.33	7.83	17.28	30.44	26.79	1.98	0.56	9.67	3.91	1.53	100
Milk	11.17	11.21	8.64	15.92	25.68	22.29	5.53	1.56	10.16	8.29	1.93	100
Eggs	2.78	3.12	6.58	12.65	25.72	38.36	3.53	0.52	7.53	3.68	1.43	100
Total	100	100										

Source: Prepared by the authors based on Table 4 and TAC/CGIAR 1992.

The CGIAR has a worldwide mandate. Because of its broad coverage, and because of the limitations of the agroecological zone classification system it used, the information had to be aggregated to some degree. This substantially curtails its potential contribution at the regional (or subregional) level. Moreover, the availability of high-quality information varies tremendously from one region to another. Because all the regions were analyzed with the same model, it was necessary to find a lowest common denominator. This means that only such information as was available for all the regions could be used. Another very serious limitation of the AEZ regionalization approach, already acknowledged by the TAC, is that the FAO classification system overlooks soil variables (crucial for agriculture) and topographic characteristics in defining the parameters of the regions, limiting itself to temperature and rainfall. This constraint, undoubtedly dictated by the lack of soil information at the world level, seriously detracts from the accuracy of the model at higher scales of analysis.

In this general framework, the major drawbacks are the following:

- Those pertaining to any "congruence" model. As the TAC working group itself points out, the congruence approach "assumes that the opportunities for research to generate new knowledge to increase productivity are equal across commodities," and adds, "[t]he value of new knowledge produced by research is proportional to the value of output, ignoring the cost of inputs or value added by processing."

- The baseline values for calculating results introduce a bias into the priority-ranking process because of the high incidence of the three indicators being used. The method measures "efficiency" according to VOP (value of production), "equity" according to the number of poor, and "sustainability" by usable land. The bias emerges when regions where countries are larger receive a higher score. Even though the TAC acknowledges that greater impact will be obtained in zones with a higher VOP, this may not necessarily occur when benefit/cost relations are analyzed, or when efficiency is measured from the standpoint of use of resources and returns to society.

- If the number of poor is used as an indicator of equity, it is not clear whether or not this measure reflects a basic basket of subsistence goods and services differentiated by zone. If it does not, the difference between rural and urban poverty goes undetected.

- Taking usable land as an indicator of sustainability may show a positive correlation with the risk of degradation, but not necessarily. Some indicator should be incorporated that shows the use of the land or information on prevailing production systems.

- By using the "modifiers," the TAC has attempted to weigh other factors relevant to the objectives of the CGIAR; such a methodology is not transparent for decision makers. In this case, it would be more transparent to use a scoring model that assigned explicit weights to all the variables under consideration and that incorporated decision makers from the very beginning of the priority-setting process.

- The TAC claims to be a demand model for setting priorities over the medium and long term. However, it fails to factor in new trade opportunities or market trends. Most of the indicators and modifiers used in the analysis come from historical or current information. This strongly conditions the outcome of the exercise toward preserving the status quo.

ADAPTING THE TAC MODEL FOR LAC: PRIORITIES BY ZONES AND COMMODITIES

Objectives

This chapter offers a limited proposal to fine-tune the TAC methodology for setting research priorities in LAC, based on the original TAC approach and database. As stated in the introduction to this document, the purpose is merely to provide an initial information tool useful in making decisions on priorities and allocation of external resources for the region. Its use should provide gains in efficiency.

Assumptions and Definitions

Users (Clients)

The main clients of the exercise in setting priorities for LAC will presumably be donors (IDB, World Bank) and other institutions that supply CGIAR funding or finance regional and national programs.

Long-term horizon

To keep this exercise consistent with the work the TAC has done, and to facilitate comparisons, the year 2010 is taken as the planning horizon for determining future demands for technology.

Levels of priority

Geography

In keeping with the work of the TAC, the geographic level is defined according to the nine agroecological zones set for LAC (see Appendix A).

Commodities

This exercise used the same classification of crops and livestock defined by the TAC.

Topics and activities

Although the TAC classification was used, it should undergo a conceptual review in the future, based on the results of the inventory whose use and application are described below.

Such a conceptual review is justified because the recommendations cannot be implemented until the AEZs have been redefined, and until the necessary information becomes available.

Technology

Technologies are defined as the result of investments intended to increase the general store of knowledge and solve research problems. Research problems in the 1990s and into the next century will presumably be different from those of the past 30 years. Therefore, many of the technologies required will be different from those of the past.

Research problems should respond to three primary concerns:

Efficiency	Increase the supply of foodstuffs and marketable goods and provide a means to meet future demand.
Equity	Improve conditions of income and consumption among the poorest groups of society.
Sustainability	Provide ways to maintain and improve the natural production base.

Technologies should be recommended in the framework of these three objectives, avoiding conflict as much as possible. When necessary, research should delve into changes in legal structures, regulations, economic and social incentives, input and product prices, macroeconomic policies, and the like, so as to provide government officials and other economic agents with the tools they need to minimize such conflicts.

Participatory model

Because the model is participatory, managers and directors (decision makers) are expected to be involved on two levels:

- Formulation. This is a scoring model. A diverse group of decision makers sets the weights for each criterion and offers recommendations on future opportunities for research.
- Decision making. This model, like the TAC model, generates different alternative outcomes for decision-making.

Priorities by Zone

Appendix B describes the formulas and equations used in setting priorities, as given in the TAC/LAC model. The results are presented in the following sequence:

Agriculture

The TAC methodology produces three tables ranking the nine agroecological zones, described in Appendix A, according to each of the three criteria (efficiency, equity, and sustainability).

Table 6. Efficiency.

Zone	VOP	GDP	Weighted score
1	73.4	87.2	80.4
2	198.3	120.2	159.2
3	181.8	110.2	146.0
4	128.2	75.8	102.0
5	50.0	120.2	85.1
6	28.3	128.8	78.5
7	195.9	117.3	156.6
8	115.0	123.0	119.0
9	29.1	117.3	73.2
	1000.0	1000.0	1000.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

The criterion of efficiency is based on two categories:

- VOP: Value of production in each zone.
- Yield gap: Gap between yields attainable with available technology and yields actually obtained with the technology being used in each zone.

The values are normalized so they will total 1000. The methodology for constructing these figures was described in detail in the previous section.

Figures in both categories were weighted with a factor of 0.5 for this initial exercise to get the last column (weighted score). These weights work in the same way as the TAC modifiers. If the value of production is considered a more significant criterion of efficiency, it can be given a greater weight (more than 0.5). Automatically, the weight (importance) attributed to the factor "yield gap" falls below 0.5. This type of modifier is called an "interfactoral modifier," because it changes the relative importance of the different factors under a single criterion.

The interpretation of Table 6 is that zone 2 would hold the highest priority on the basis of efficiency alone. Any additional resources for research will have a greater impact here than in other zones in terms of increasing the value of production and reducing the yield gap.

Table 7. Equity.

Zone	Poor	GDP	Weighted score
1	82.4	105.0	93.7
2	144.9	114.6	129.8
3	196.7	97.8	147.2
4	321.9	83.7	202.8
5	29.2	112.9	71.0
6	7.6	136.7	72.2
7	129.4	117.3	123.3
8	53.5	134.7	94.1
9	34.4	97.3	65.9
	1000.0	1000.0	1000.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

Poor (poverty level): This factor is defined as the number of rural and urban poor in each zone.

Per capita GDP: Gross domestic product per person. Because purchasing power varies considerably among countries, this factor should actually be adjusted with an indicator of purchasing power in each region. No such adjustment was used in this report because the necessary information was not available.

Weighted score: Each of the two categories (poverty and GDP) was weighed by a factor of 0.5. Table 7 shows that region 4 holds the highest priority from the standpoint of equity.

Table 8. Sustainability.

Zone	Usable land	Risk of degradation	Food pressure	Weighted score
1	78.7	149.1	129.5	119.1
2	221.0	212.4	90.9	174.8
3	304.4	32.3	105.6	147.4
4	119.7	129.2	141.4	130.1
5	34.6	113.0	157.0	101.5
6	18.3	150.3	40.4	69.7
7	102.4	60.9	97.3	86.9
8	93.2	62.1	60.6	72.0
9	27.9	90.7	177.2	98.6
	1000.0	1000.0	1000.0	1000.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

Usable land, risk of degradation and food pressure (urgency) were defined in the previous section ("The TAC Model for Latin America and the Caribbean"). The weighted scores in the last column were figured by assigning equal weights (0.33) to all three factors.

Table 9. Final scores for agriculture by geographic zone.

Zone	Efficiency	Equity	Sustainability	Final score
1	80.4	93.7	119.1	97.9
2	159.2	129.8	174.8	154.8
3	146.0	147.2	147.4	146.9
4	102.0	202.8	130.1	144.8
5	85.1	71.0	101.5	86.0
6	78.5	72.2	69.7	73.4
7	156.6	123.3	86.9	121.9
8	119.0	94.1	72.0	94.8
9	73.2	65.9	98.6	79.4
	1000.0	1000.0	1000.0	1000.0

Sources: Tables 6, 7, and 8.

Under this model, the weight of each criterion can also be changed with the use of modifiers. These are called "intercriteria modifiers." In the above table, each of the three factors received the same weight (0.33). However, if one factor, such as sustainability, holds more relative importance and should have greater weight, the figure can be raised to more than 0.33.

The configuration used here, with equal weights for all three criteria, assigns the highest priority to zone 2 as the geographic area where more resources should be allocated. In this zone, investments in research would produce a simultaneous impact on efficiency, equity, and sustainability greater than in the other zones.

Forestry

Table 10. Efficiency.

Zone	VOP
1	34.9
2	205.7
3	369.4
4	135.1
5	3.7
6	5.1
7	171.3
8	26.4
9	48.4
	1000.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

VOP figures for forestry differ from those in agriculture, as they are calculated to include such products as marketable sawlogs and fuelwood.

Table 11. Equity.

Zone	GDP	Fuelwood per capita	Weighted score
1	105.0	150.8	127.9
2	114.6	142.8	128.7
3	97.8	293.6	195.7
4	83.7	44.3	64.0
5	112.9	96.7	104.8
6	136.7	53.5	95.1
7	117.3	57.0	87.2
8	134.7	59.9	97.3
9	97.3	101.3	99.3
	1000.0	1000.0	1000.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

In the future, per capita GDP should be adjusted to reflect purchasing power in each region.

Table 12. Sustainability.

Zone	Wooded area	Food pressure	Risk of degradation	Weighted score
1	88.4	149.1	129.5	122.3
2	267.6	212.4	90.9	190.3
3	403.6	32.3	105.6	180.5
4	104.3	129.2	141.4	125.0
5	22.7	113.0	157.0	97.6
6	4.5	150.3	40.4	65.1
7	52.2	60.9	97.3	70.1
8	29.9	62.1	60.6	50.7
9	27.2	90.7	177.2	98.4
	1000.0	1000.0	1000.0	1000.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

The concept of wooded area is described in more detail above in the section entitled "The TAC Model for Latin America and the Caribbean," which also explains the risk of degradation and food pressure (urgency). For this exercise, the same weight (0.33) was used for all three categories.

Table 13. Final weighting for the forestry sector, by zone.

Zone	Efficiency	Equity	Sustainability	Final score
1	34.9	127.9	122.3	95.3
2	205.7	128.7	190.3	175.1
3	369.4	195.7	180.5	247.9
4	135.1	64.0	125.0	108.2
5	3.7	104.8	97.6	69.0
6	5.1	95.1	65.1	55.2
7	171.3	87.2	70.1	109.1
8	26.4	97.3	50.7	58.1
9	48.4	99.3	98.4	82.2
	1000.0	1000.0	1000.0	1000.0

Source: Tables 10, 11, and 12.

Scores for the forestry sector show that zone 3 holds the highest priority, which is different from the results for agriculture. The fisheries sector was not addressed here because too little information was available by agroecological zone in LAC.

Priorities by Commodity, Adjusting for Opportunities

Incorporating citeria of "opportunity"

Bearing in mind the limitations inherent in the TAC model for LAC, as described above, the original model was modified by applying an indicator of future opportunities for each commodity. The use of such a criterion is problematic for this kind of model, resting as it does on the basic assumption of present congruence. It raises the dilemma of how to assign a priority ranking to compare a product with a very high production value to another, whose current production may be minimal (or zero). There is no easy solution to this problem, even though it does not necessarily violate the assumption of convergence. Instead, the idea is to reconcile present congruence with future congruence. The emergence of new products with a growing international market can certainly raise the demand for resources to cover research and development, and this leads to the problem of setting priorities among the various new opportunities and between these and the traditional products from each AEZ, whose markets are better consolidated.

Proposed method and results

The first task is to gauge relative opportunities for the different commodities in each AEZ. The following approach could be used:

1. Rate the agroecological potential of the zone for each commodity on a scale of 0 to 9. Appendix D gives a form used for quantifying the agroecological potential of the different AEZs in LAC.

2. Simplify the information by eliminating commodities that are not appropriate for cultivation in the AEZ (any original ranking less than 7 is reclassified as 0).

3. This leaves four categories for consideration:

   3: Maximum agroecological potential, rated 9 on the agroecological potential questionnaire.
   2: Commodities rated 8.
   1: Commodities rated 7.
   0: Commodities rated from 0 to 6.

4. Weight these categories to give final figures on agroecological potential:

Commodities with a reclassified potential of 3 for the AEZ:
3 / (1+2+3) = 0.5
Reclassified aptitude of 2: 2 / (1+2+3) = 0.33
Reclassified aptitude of 1: 1 / (1+2+3) = 0.17

5. Obtain estimated likely growth rates of demand (annual average rate through the year 2000) for commodities included in the TAC list. Using this information, classify the products into four categories of future demand: 3, 2, 1 and 0, corresponding to growth rates that are high, medium, low and negligible or negative[2]. The questionnaire given in Appendix D was designed as an aid in obtaining information on growth rates of demand.

6. Derive the opportunity indicator by multiplying the indicator of future demand for a commodity by the agroecological potential rating of the particular zone. Thus, the opportunity indicator for a commodity can take one of the nine values shown in Table 14

Table 14. Opportunity indicator.

Future demand	Agroecological potential		
	High (0.5)	Medium (0.3)	Low (0.17)
High (3)	1.5	0.99	0.55
Medium (2)	1.0	0.66	0.34
Low (1)	0.5	0.33	0.17

Source: Prepared by the authors.

The next step is to figure a priority ranking for commodities in each AEZ, using a combined index of production value and opportunity indicator.

Questionnaires were designed to gauge agroecological potential and growth of demand (see Appendix D). IICA's cooperative programs were then used as a vehicle for distributing the questionnaires among various national agricultural research institutes (NARIs), representing all nine AEZs in LAC. Because the responses varied so widely,

2 If "t" is the growth rate, the four categories are defined as:

Negligible	$t \leq 0 = 0$
Low	$0 < t < 1 = 1$
Medium	$1 < t \leq 2 = 2$
High	$t > 2 = 3$

especially with regard to agroecological potential, an outside expert was contacted to guide decisions on the values of agroecological potential for AEZs 2 and 3. The exercise covered only those commodities for which the World Bank had provided estimates on annual demand growth from 1991 through 2005. Given the limitations of the information at hand, the results are presented only as an exercise suggesting ways to incorporate the concept of opportunities into priority setting for commodities.

Table 15. Information on growth rate of demand, agroecological potential and calculation of opportunity index for certain commodities.

Commodity	Original data			Ranked data			Opportunity index	
	Population growth (%)	Potential		Demand	Potential			
		ZAE2	ZAE3		ZAE2	ZAE3	ZAE2	ZAE3
Rice	2.70	8	9	3	0.33	0.5	0.99	1.5
Wheat	3.00	1	1	3	0	0	0.00	0.00
Maize	2.50	8	8	3	0.33	0.33	0.99	0.99
Sorghum	2.50	8	7	3	0.33	0.17	0.99	0.51
Banana	1.30	9	9	2	0.5	0.5	1.00	1.00
Soybean	3.10	8	8	3	0.33	0.33	0.99	0.99
Orange	2.40	8	8	3	0.33	0.33	0.99	0.99
Lemon & lime	2.40	8	8	3	0.33	0.33	0.99	0.99
Sugarcane	2.10	8	9	3	0.33	0.5	0.99	1.00
Coffee	1.00	6	5	1	0	0	0.00	0.00
Cocoa	0.30	9	9	1	0.5	0.5	0.50	0.50
Jute	2.80	8	9	3	0.33	0.5	0.99	1.50
Palm oil	8.10	8	9	3	0.33	0.5	0.99	1.50

Source: Prepared by the authors, based on World Bank data on demand growth for agricultural commodities.

Finally, the production value information presented in Table 5 and the opportunity index calculated in Table 15 can be combined to give the priority for each commodity, as shown in Table 16.

Information on VOP is normalized to a base of 1000. The values of the commodities reflect a ranking based on VOP. For example, the column on AEZ2 shows that oranges, coffee, and sugarcane are the most important products in this agroecological zone. The same products occupy the first three places in AEZ3.

The information on opportunities given in Table 15 is adjusted to a basis of 1000 in Table 16. The weights (percentages) to be applied to the VOP and opportunity index are then determined. In this case, 70 percent of the final result is determined by the present VOP, and 30 percent, by future opportunities.

Table 16. VOP rank adjusted according to the opportunity index.

Commodity	VOP base 1000		Opportunity index (OI) (base 1000)		Adjusted rank order 0.7(VDP) + 0.3(OI)	
	AEZ2	AEZ3	AEZ2	AEZ3	AEZ2	AEZ3
Rice	65.96	96.51	95.10	125.31	74.70	105.15
Wheat	0.00	0.00	0.00	0.00	0.00	0.00
Maize	85.34	77.75	95.10	82.71	88.27	79.24
Sorghum	13.46	1.09	95.10	42.61	37.95	13.54
Banana	64.26	98.32	96.06	83.54	73.80	93.89
Soybean	126.90	103.06	95.10	82.71	117.36	96.95
Orange	287.36	227.56	95.10	82.71	229.68	184.10
Lemon/lime	24.85	26.14	95.10	82.71	45.93	43.11
Sugarcane	139.56	133.77	95.10	125.31	126.23	131.24
Coffee	147.70	171.56	0.00	0.00	103.39	120.09
Cocoa	42.45	48.86	48.03	41.77	44.13	46.73
Jute	0.12	0.18	95.10	125.31	28.62	37.72
Palm oil	2.03	15.20	95.10	125.31	29.95	48.24
TOTAL	1000	1000	1000	1000	1000	1000
Weight		0.7		0.3		1

Source: Prepared by the authors.

The decision on how to distribute the weighting factor between VOP scores and the opportunity index will reflect a trade-of between a desire to attach high priority to "traditional" products, and a willingness to assume certain risks regarding an uncertain but attractive future.

This adjusted order reverses the priority of sugarcane and coffee in AEZs 2 and 3, in comparison with the VOP ranking. This is because sugarcane has a higher opportunity index than coffee for both zones. Ideally, the demand for sugarcane will grow more rapidly than the demand for coffee, as sugarcane is a more suitable crop for both zones (see Table 15).

In AEZ3, when the VOP rank order is adjusted using the opportunity index, the score of palm oil rises from 15.20 to 48.24, surpassing even cocoa (46.73) and lime/lemon (43.11), despite the higher VOPs of the latter. This is because of the effect of the weight factors, with palm oil showing a higher opportunity index because it is more suited for cultivation in AEZ3 or anticipates higher growth of demand than cocoa and lime/lemon (see Table 15).

The final "adjusted" ranking can be an important tool in reallocating research and development resources, based on anticipated new trade opportunities over the medium term.

It should be stressed a table such as this is useful for comparing VOP rank order adjusted by opportunities only within each AEZ.

Finally, the incorporation of future opportunities into the priority analysis requires greater methodological development, especially for measuring agroecological potential and showing how it interacts with other socioeconomic factors. It may also require further fine-tuning of agroecological zoning. The classification of AEZs used here, as noted by Wood and Pardey (1993:39-40), is too broad to reveal the potential production advantages of similar production areas.

RECOMMENDATIONS AND SUGGESTIONS

The region should find methods for priority-setting that will minimize the limitations of the TAC model, described in this chapter. One possibility might be the gradual implementation of methods for analyzing the region's priorities, beginning with simple procedures such as the adjusted scoring methods for LAC (improved scoring) as described above.

As the region improves its skills at strategic analysis, it should develop models that fully incorporate the costs and benefits of research, with indicators that more realistically describe efficiency and more accurately incorporate the criterion of sustainability. Another important consideration involves new market openings for the region's products. This circumstance requires a better methodological approach, with an urgent need to explore how these markets will operate and how they can be measured.

Members of the group also examined objectives (criteria) and agree that efficiency and sustainability are both important. There is some question about indicators of equity. Various social groups are covered, including small-scale farmers, farm workers (employment), cash-crop producers, the urban poor, nutrition, and the like. While it is clear that technology has certain effects on these groups, the effects are so diverse and the trends are so unpredictable that the issue is a difficult one to manage. If this item is to be included in the priority-setting process, better ways need to be found for conceptualizing and handling it.

More appropriate indicators of efficiency are also needed, such as the effect of foreign trade (the absolute value of the total export and import balance). Also useful would be the payoff of each commodity (indicators of cost/benefit, internal rate of return, investments in producing or researching the commodity), together with the yield gap, yield growth rate, indicators of added value, indicators of comparative and competitive advantages, cost of domestic resources, and future market demand. With these additions, the criterion of efficiency could be made more accurate.

Sustainability can be reflected with indicators of land-use intensity and potential, based on such factors as risk of erosion and indicators of agrochemical use.

It is not clearly understood how technology affects income, employment, natural resources, and so forth. The impact of technology would be a useful area for future inquiry, so that indicators for subsequent resource allocation models can be improved. Models developed for the region should have certain features such as:

1. **Transferability**

   Methods should facilitate assimilation and replication by a broad range of subregions and countries.

2. **Transparency**

   Methods for calculation and aggregation require a number of variables. These variables should be put together according to a clear process based on a simple structure that embraces the relationships among criteria, variables, indicators, and weights, free of ambiguities and easily understandable.

   Even if methods for obtaining certain indicators are very sophisticated, the final stage of scoring should be transparent, as managers and decision makers from institutions intervene directly.

3. **Participatory method**

   The mechanism should facilitate interaction among the various components of participating institutions, such as decision makers, researchers at various levels, planners, and, if possible, other sectors outside the institutions.

These processes can be carried out to greatest advantage if people in the region are trained in the subject, and if substantial efforts are made to build databases for the same purposes.

APPENDIX A

Definitions, Agroecological Zones, and Agroecological Zones in LAC

Definitions

Tropics:	Year-round mean monthly temperature above 18°C, corrected to sea level.
Subtropics:	One or more months with monthly mean temperature below 18°C, corrected to sea level.
Temperate:	One or more months with monthly mean temperature below 5°C, corrected to sea level.
Length of growing period (LGP):	Relationship between soil moisture and potential evapotranspiration (in days).
Warm:	Daily mean temperature above 20°C during the growing period.
Cool:	Daily mean temperature between 5°C and 20°C during the growing period.
Cold:	Daily mean temperature below 5°C.
Warm/cool:	Daily mean temperature above 20°C during part of the growing period, and below 20°C the rest of the year.
Arid:	LGP less than 75 days.
Semiarid:	LGP from 75 to 180 days.
Subhumid:	LGP from 180 to 270 days.
Humid:	LGP more than 270 days.

Agroecological Zones

Warm, arid, and semiarid tropics: Semiarid moisture zone in the tropics. Arid moisture zone included for purposes of irrigation and rangeland assessment, and for reconciliation with political boundaries. Daily mean temperature during the growing period above 20°C.

Warm, subhumid tropics: Subhumid moisture zone in the tropics. Daily mean temperature during the growing period above 20°C.

Warm, humid tropics: Humid moisture zone in the tropics. Daily mean temperature during the growing period above 20°C.

Cool tropics: Semiarid subhumid and humid moisture zones in the tropics. Daily mean temperature during the growing period from 5°C to 20°C. Includes moderately cool tropics with daily temperatures from 15°C to 20°C.

Warm, arid, and semiarid subtropics with summer rainfall: Semiarid moisture zone in the subtropics, and some arid zones. Daily mean temperature during the growing season above 20°C.

Warm, subhumid subtropics with summer rainfall: Subhumid moisture zone in the subtropics. Daily mean temperature during the growing period above 20°C.

Warm/cool, humid subtropics with summer rainfall: Humid moisture zone in the subtropics. Daily mean temperature above 20°C during the warm part of the growing period, and below 20°C during the cool part of the growing period. The cool part is moderately cool with daily mean temperature from 15°C to 20°C.

Cool subtropics with summer rainfall: Semiarid, subhumid, and humid moisture zones in the subtropics. Daily mean temperature during the growing period from 5°C to 20°C. Includes moderately cool subtropics.

Cool subtropics with winter rainfall: Semiarid, subhumid, and humid moisture zones in the subtropics. Daily mean temperature during the growing period from 5°C to 20°C.

Agroecological Zones in LAC

AEZ1 - WARM ARID AND SEMI-ARID TROPICS.
Antigua, Suriname, Haiti, parts of Bolivia, Brazil, Cuba, Ecuador, Mexico and Venezuela.

AEZ2 - WARM SUBHUMID TROPICS.
Bahamas, Dominican Republic, Guadeloupe, Martinique, St. Lucia, and parts of Bolivia, Brazil, Costa Rica, Cuba, Ecuador, El Salvador, Mexico, Paraguay and Venezuela.

AEZ3 - WARM HUMID TROPICS.
Barbados, Belize, French Guiana, Guyana, Jamaica, Nicaragua, Panama, Puerto Rico, Suriname, Trinidad and Tobago, Windward Isles, and parts of Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Peru and Venezuela.

AEZ4 - COOL TROPICS
Parts of Bolivia, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico and Peru.

AEZ5 - WARM ARID AND SEMI-ARID SUBTROPICS WITH SUMMER RAINFALL.
Parts of Argentina and Mexico.

AEZ6 - WARM SUBHUMID SUBTROPICS WITH SUMMER RAINFALL.
Parts of Argentina.

AEZ7 - WARM/COOL HUMID SUBTROPICS WITH SUMMER RAINFALL.
Parts of Argentina, Brazil and Paraguay.

AEZ8 - COOL SUBTROPICS WITH SUMMER RAINFALL.
Uruguay and parts of Argentina.

AEZ9 - COOL SUBTROPICS WITH WINTER RAINFALL.
Chile and parts of Argentina.

APPENDIX B

Mathematical Formulation of the Priority-setting Model

As was stated in this chapter, the exercise began with a simple scoring model based on information from the TAC study. Certain basic criteria were selected as a basis for setting priorities, and indicators were provided for each one, insofar as available information permitted. The result was presented according to the AEZs defined by the TAC work group.

Analytically, the model begins with the following definitions and derives a final result through a series of equations:

We define Z_i $i = 1...9$

C_j $j = 1...3$

$I_{j,k}$ $k = 1...n, j = 1...3$

where Z_i represents the different AEZs, C_j, the criteria selected for setting priorities, and $I_{j,k}$ the k indicators used for each criterion j.

Weight factors α_i, where $i = 1...n$, are defined as $\Sigma\ \alpha_i = 1$, with $0 \leq \alpha_i \leq 1$. These weights are applied to each of the criteria C_j in the final result. Weight factors β_i, with $i = 1...n$, calculated as $\Sigma\ \beta_i = 1$, where $0 \leq \beta_i \leq 1$ are applied to each of the indicators $I_{j,k}$.

The final result for each AEZ R_{Z_i} would be $R_{Z_i} = \Sigma\ P_j$ for $j = 1...3$

where $P_j = C_1\alpha_1 + C_2\alpha_2 + C_3\alpha_3$

where $C_1 = I_{1,1}\beta_1 + I_{1,2}\beta_2 + ... + I_{1,n}\beta_n$

If a 1000 base is selected, the relative importance of each AEZ will depend on the value it receives, as

$$\Sigma R_{Z_i}\text{-}1000$$

APPENDIX C

Values for the Forestry Sector

Table 1. Baseline values for setting forestry priorities by agroecological zone (x 000).

AEZ	VOP	Nº of POOB	Usable land	Baseline value
Weights	**0.17**	**0.33**	**0.5**	
1	34.9	82.4	88.4	77.3
2	205.7	144.9	267.6	216.6
3	369.5	196.7	403.6	329.5
4	135.1	321.9	104.3	181.3
5	3.7	29.2	22.7	21.6
6	5.1	7.6	4.5	5.6
7	171.3	129.4	52.2	97.9
8	46.4	53.5	29.5	36.9
9	48.4	34.4	27.2	33.2
	1000.0	1000. 0	1000. 0	1000. 0

Source: Prepared by the authors based on TAC/CGIAR 1992.

Table 2. . Quantitative impact of modifiers on forestry, with a weight of 0.5.

AEZ	Baseline value	Forest (+)	GDP (-)	Soil (-)	Size (-)	New baseline	% Change
1	77.30	-2.58	-0.49	6.31	-22.30	58.24	-24.66
2	216.60	-13.00	-9.04	-3.52	29.0 0	220.04	1.59
3	329.50	144.90	6.56	-61.74	31.23	450.45	36.71
4	181.40	-70.10	12.99	20.42	-52.30	92.41	-49.06
5	21.60	-4.60	-0.76	2.97	2.17	21.38	-1.02
6	5.60	-2.00	-0.70	0.45	0.87	4.22	-24.64
7	97.90	-33.70	-5.04	21.38	4.39	84.93	-13.25
8	36.90	-12.40	-4.25	7.99	3.70	31.94	-13.44
9	33.20	-6.60	0.72	5.72	3.33	36.37	9.55
	1000.00	-0.1	0.0	0.0	0.1	1000.0	0.0

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

Table 3. Percent distribution of gross value of production, adjusted by priority of AEZs for the forestry sector.

Commodity	VOP LAC	Adjusted VOP LAC	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	TOTAL
Traded sawlogs	12.5	12.4	0.53	20.7	53.9	8.64	0	0.01	4.33	0.29	11.64	100
Nontraded sawlogs	41.4	43.2	0.57	23.4	57	6.11	0	0.8	4.53	4.37	3.178	100
Fuelwood	46.1	44.4	12.4	21	31	12.4	4.81	0.16	13.5	2.86	1.857	100
	100	100										

Source: Prepared by the authors based on Table 1 and TAC/CGIAR 1992.

APPENDIX D

Forms for Obtaining Information

Table 4. Evaluation of production potential for particular products by agroecological zone.

Commodity	1	2	3	4	5	6	7	8	9
Rice	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Wheat	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Maize	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Barley	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Sorghum	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Millet	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Cassava	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Potato	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Sweet	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
potato	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Yam	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Banana,	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
plantain	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Chick-pea	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Cowpea	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Pigeon	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
pea	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Broad	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
bean	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Lentil	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Soybean	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Groundnut	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9

Table 4. (Continued).

Commodity	1	2	3	4	5	6	7	8	9
Coconut	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Tomato	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Onion	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Cabbage	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Orange	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Lemon & lime	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Pineapple	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Grape	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Apple	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Sugarcane	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Coffee	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Tea	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Cocoa	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Tobacco	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Rubber	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Cotton	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Jute	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Hemp	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Sisal	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
Palm oil	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9

Table 4. (Continued).

Commodity	1	2	3	4	5	6	7	8	9
Beef, buff-	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
alo meat	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Sheep &	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
goat meat	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Pig meat	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Poultry	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
meat	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Milk	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9
Eggs	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9	5 6 7 8 9

Instructions: Evaluate the agroecological potential of each zone for producing each commodity. Circle a number from 0 (no potential) to 10 (maximum potential).

Source: Prepared by the authors.

Determining Future Demand for Agricultural Commodities from LAC

This form was designed to set certain parameters on the growth of demand for agricultural commodities produced in LAC. The results can be combined with additional information to build an indicator of future opportunities for research in the region.

Based on their knowledge of markets for these commodities, informants should estimate a probable range within which demand is likely to grow, as an annual average, from 1993 to the year 2000.

A hypothetical example is given below to help informants understand the questionnaire more clearly.

Example. Mangoes of all varieties are consumed in LAC and exported to Europe and the United States. Exports are expected to continue from 1993 through 2000, to these markets only. If D_m is the total demand for mangoes in LAC, this can be expressed as:

$$D_m = D_{m(LAC)} + D_{m(Eur)} + D_{m(US)}$$

Where:

$D_{m(LAC)}$ = demand for LAC mangoes in LAC.

$D_{m(Eur)}$ = demand for LAC mangoes in Europe.

$D_{m(US)}$ = demand for LAC mangoes in USA.

Informants are asked to select one of four ranges describing the likely average annual growth rate of demand for mangoes from LAC from 1993 through 2000. In other words, informants should select the range of **average** annual percent variation:

$$\frac{D_{m(total)t} - D_{m(total)t-1}}{D_{m(total)t-1}} \quad ; t = 1994,\ldots,2000$$

$D_{m(total)t}$ is the total demand for mangoes in year *t* (this average depends on whether demand will expand or contract in each of the three markets).

If informants believe the annual average growth of demand for mangoes from LAC from 1993 to 2000:

i. will be negligible or negative, the range $r \leq 0$ should be marked on the corresponding line;

ii. will be from 0% to 1%, the range $0 < r < 1$ should be marked;

iii. will be from 1% to 2%, the range $1 \leq r < 2$ should be marked;

iv. will be greater than or equal to 2%, the range $r \geq 2$ should be marked.

Of course, not all commodities have the same markets, but in all cases, total demand for a product includes at least the demand in LAC.

Because the names of many agricultural commodities vary from one country of LAC to another, but the names in English tend to be more uniform, the list of commodities on the questionnaire is given in English.

Questionnaire to Evaluate the Growth of Total Demand for Agricultural Commodities from LAC

For each commodity, mark the expected range of r, where

r = average annual growth rate of total demand for products from LAC, 1993-2000

Commodity	r _ < 0	0 ≤ r _ < 1	1 ≤ r _ < 2	2 < r
1. Rice				
2. Maize				
3. Wheat				
4. Barley				
5. Sorghum				
6. Millet				
7. Cassava				
8. Potato				
9. Sweet potato				
10. Yam				
11. Banana, plantain				
12. Chick-pea				
13. Cowpea				
14. Pigeon pea				
15. Broad bean				
16. Lentil				
17. Beans				
18. Soybean				
19. Groundnut				
20. Coconut				
21. Tomato				
22. Onion				

Commodity	r_ < 0	0 ≤ r_ < 1	1 ≤ r_ < 2	2 < r
23. Cabbage				
24. Orange				
25. Lemon & lime				
26. Pineapple				
27. Grape				
28. Apple				
29. Sugarcane				
30. Coffee				
31. Tea				
32. Cocoa				
33. Tobacco				
34. Rubber				
35. Cotton				
36. Jute				
37. Hemp				
38. Sisal				
39. Palm oil				
40. Beef, buffalo meat				
41. Sheep, goat meat				
42. Pig meat				
43. Poultry				
44. Milk				
45. Eggs				

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Chapter 4

ANDEAN ZONE SUBPROJECT: FINAL REPORT

Rafael Posada et al.

CONTENTS

INTRODUCTION

This report was written by Rafael Posada, consultant and coordinator for the subproject at the IICA Office in Colombia. The report covers the activities of a working group made up of Luis Romano, Head of the Strategic Planning Division at the Colombian Agricultural Institute (IICA); Julio Palomino, Director of Planning at the National Agricultural Research Institute (INIAP) of Ecuador; and Luis Alvarado, Manager of Planning at the National Agricultural Research Fund (FONAIAP) of Venezuela. Overall coordination, in the context of the IICA/IDB project, was provided by Eduardo Lindarte, of Program II at IICA Headquarters. Important contributions were made by Edgardo Moscardi, IICA representative in Colombia; Nelson Rivas, Executive Secretary of the Cooperative Agricultural Research and Technology Transfer Program for the Andean Subregion (PROCIANDINO); Hector Medina, of Program II at IICA Headquarters, and Eugenio Cap, Director of Strategic Planning at the National Institute of Agricultural Technology (INTA) in Argentina. Finally, the author wishes to express his appreciation to the directors of IICA, INIAP, and FONAIAP, without whose support this work not have been possible.

At the first working session of the IICA/IDB Project on Regional Priorities for Agricultural Research, held in Bogota, Colombia, it was decided that the program of activities should provide for expanding and applying the TAC model in the Andean zone.

Specifically, it was proposed that a methodology for submitting regional research project profiles should be developed and tested through pilot programs.

For the sake of efficiency, it was decided that this effort should involve the active participation of three of the five Andean zone countries, namely, Colombia, Ecuador, and Venezuela. Insofar as possible, however, the project profiles to be developed and submitted were to address problems affecting the entire region; thus, any potential solutions developed through the research projects would be applicable in every country in the zone.

Bearing in mind the need to facilitate operations and logistical arrangements, it was also decided that the exercise should focus on five products of the agricultural sector; hence, subsectors such as forestry, fisheries, and aquaculture would not be included for the time being.

It was decided that the Andean zone subproject should pursue the following four objectives:

— To review mechanisms for establishing priorities for agricultural research in the subregion

— To identify priority products on which the countries might wish to conduct research, bearing in mind their usefulness to the entire region, including Peru and Bolivia

— With respect to each product selected, to identify a topic on which research could be carried out through interinstitutional cooperation among the national research centers of the three countries

— For each of the topics identified, to draw up a project profile of regional scope, identifying those research resources that could be contributed by each of the participating institutions.

The purpose of reviewing priority-setting mechanisms was to identify similarities in the criteria and methodologies followed by different national and international institutions, as regards the allocation of research resources.

Another aim was to ascertain whether research plans were stable, given the internal dynamics of the economic and social forces operating in individual countries. This has become particularly important in recent years, when structural adjustment plans and policies aimed at internationalizing the economy have changed the role of the State and its approach to the management of macroeconomic and sectoral variables that have a direct bearing on the global and sectoral allocation of resources.

Some of the criteria applied to horizontal cooperation on agricultural research projects will be determined by the new development model being implemented by the countries, which is based on opening up the economy to international markets and maximizing relative and/or competitive advantages. Indeed, the decision to fund and implement a particular regional project must not be based solely on the fact that the countries of the region happen to agree on the priority that should be assigned to a given agricultural commodity. The participating countries should explicitly state their interest in collaborating on such projects, and this statement of interest should be a prerequisite for including a product in agricultural research plans at the regional level.

The idea of planning agricultural research that is regional in scope is based on the assumption that certain obstacles to proper crop management or optimum utilization of available natural resources are common to the different areas in which the target commodities are produced. Although this assumption is a valid one, the fact is that in practice, these problems affect the different zones in different ways. It was therefore deemed important to identify research topics that would be of interest to all the countries.

It was suggested that drawing up project profiles should make it possible to identify and combine those research resources that are available in the region. This is particularly important when it comes to identifying the human resources required to direct project implementation and execution, and the institutional resources required to ensure that regional project activities are included in the regular programs of participating institutions.

WORKING METHODOLOGY

Background

The methodology proposed consists of surveying the new environment for research and technology-transfer activities in agriculture, forestry, and fisheries. A number of studies and forums have already identified the conditions that affect research and transfer activities carried out in the context of development models based on the internationalization of the economy. Because of their potential importance, the main features of such activities are outlined below.

One of the main issues that needs to be addressed is the shift that has taken place with regard to objectives: from the general objective of increasing the total production of goods so as to ensure domestic supply, research and technology-transfer activities now pursue the objective of rationalizing costs and improving the quality and type of goods produced, with a view to ensuring competitiveness. A number of other changes are also related to this new emphasis on economic performance:

— The integration of agroindustrial chains creates a need for more innovative products. This, in turn, creates a greater need for field production technologies.

— The countries have adopted legal systems designed to provide copyright protection for scientific discoveries pertaining to agriculture, even to the point of patenting living organisms. In general, this means further constraints will be imposed on the flow of information and genetic materials to the less-developed countries.

— On the threshold of the biotechnology revolution, the traditional boundaries between basic and applied research are becoming blurred. This revolution could even go so far as to eliminate the so-called natural advantages enjoyed by certain geographical regions with regard to the production of certain goods. The high costs and the high risks that are involved in investing at the levels required for such research represent another constraint on the developing countries.

— The traditional role of the State in funding and executing research and technology transfer has been weakened, and private enterprise has taken over much of this work. Although the sphere of action of each of these two sectors has not been properly defined, it is generally agreed that the sector that appropriates the benefits of a research project should assume responsibility for funding it.

Another major issue to be dealt with is that of the magnitude and the scale of agricultural and rural processes in general. It has become necessary to reconsider the traditional view that nature is a self-renewable provider of free goods, and to recognize the importance of preserving the base, as well as the diversity, of natural resources in order to ensure the future viability and continuity of production activities. This opens the door to a new set of very diverse scientific and technological considerations that must be addressed by national and international research systems.

Finally, there is an increasing need to analyze the objectives of technology, as well as its impact on other areas; in particular, due consideration must be given to the need to ensure equity for the different social groups.

Although the trends outlined above reflect recent developments, it is important to bear in mind that they could condition and alter the objectives and the socioeconomic environments that need to be considered in designing regional cooperation mechanisms for research and technology transfer in the areas of agriculture, forestry, and fisheries. These issues must, therefore, be taken into account in the priority-setting process.

The international community, for its part, is also reassessing its role in the generation and transfer of new know-how for developed countries in order to ensure that any resources allocated for this purpose are used as efficiently as possible. The task becomes more complicated if the general objectives of such contributions are changed. Indeed, easy-to-measure objectives, such as that of increasing the supply of food and agricultural raw materials in the region, have given way to conceptual objectives, such as equity, sustainability, efficiency, and competitiveness. These objectives can be clearly defined only if the political, economic, and social scenarios in which the research and transfer activities are to take place are clearly identified.

It is suggested that the institutionalization of regional research and technology transfer activities in agriculture, forestry, and fisheries be aimed at strengthening the following four areas:

- The efficient use of highly specialized research resources–natural, physical, or human–that are available in the region
- The development of critical masses of research resources in order to ensure the advancement of scientific know-how in the region
- Ongoing efforts to keep the regional scientific community abreast of the latest advances in scientific knowledge in other regions or countries
- The funding of activities and/or projects that go beyond the individual capabilities of participants, and are likely to generate externalities that might be appropriated within the countries' research systems

Setting Priorities by Agroecological Zone

Planning units or objects need to be modified, along with any changes that occur in the environment within which research and transfer activities in agriculture, forestry, and fisheries are to be carried out in the immediate future.

Because the new objectives proposed are so complex and so closely interrelated, and because the application of a given technology to a given product has the potential for affecting other production resources, it has been suggested that agroecological zones be used as the new planning unit. Although there are sound reasons for proposing this approach, and it has been widely accepted, there are still serious limitations to its implementation.

The first major effort, which gave rise to this subproject on the development of agricultural research project profiles for the Andean zone, was the TAC/CGIAR exercise, in which nine agroecological zones were defined, according to rainfall and temperature. These zones are located throughout the traditionally accepted geographic regions, such as Asia, Africa, Latin America, and others.

Initially, the idea was to apply the methodology proposed by TAC/CGIAR for the developing world. This methodology is discussed in chapter 3 of this book. Problems have arisen, however, because of the lack of data for individual countries and agroecological zones.

To begin with, the agroecological zones must be redefined, with a view to bringing them in line with geographic zones that have traditionally been studied by experts in the countries, and on which basic information is already available. One methodology that will have to be applied in this effort will be the identification of suitable parameters, such as soil quality, periods of daylight, and so on, which affect the structure of prevailing production systems.

This is particularly true in the case of Andean zone products that are cultivated both in irrigated and in rain-fed areas, depending on the availability of production resources, and which, therefore, must be dealt with differently when it comes to research and transfer of technology. Similarly, in the case of certain products that have been included in regional production systems, altitude above sea level is the factor that determines what restrictions and limitations farmers have to deal with.

Another factor that hinders application of the TAC/CGIAR methodology in the Andean zone is the population density of certain areas. This makes it difficult to achieve equity, sustainability, efficiency, and competitiveness simultaneously with the resources that are available in the different regions.

The main conclusion that was reached as a result of the attempt to apply the TAC/CGIAR methodology at the subregional level was that a subregional project should be implemented with a view to identifying an appropriate methodological framework for establishing research and transfer priorities in agriculture, forestry, and fisheries according to agroecological zones defined in terms of the social, economic, and political environment of the subregion.

Until such time as this proposal could be approved, however, the regional project profiles had to be developed with the information that was available. Initially, these were limited to Colombia, Ecuador, and Venezuela.

The next steps were then identified, bearing in mind the following:

- The TAC/CGIAR exercise has pointed to a number of priorities for the allocation of resources that are available at the international level.
- Despite the aforementioned limitations, the application of the TAC/CGIAR methodology, with data broken down by country, has made it possible to indicate, in very general terms, a number of products that are of interest to all three countries.
- Efforts have already been made, using similar methodologies, to set priorities for agricultural research at the national research centers; these can be used to confirm the results mentioned in the previous paragraph.
- At present, it is the national experts who are in the best position to identify restrictions and opportunities by product and by geographic zone.
- It is important to develop common criteria for identifying and describing projects that might be considered to be of regional interest.

In the TAC/CGIAR exercise, the following agroecological zones were found to be common to at least two of the three countries:

Zone	Colombia	Ecuador	Venezuela
II	X	X	
III	X	X	X
IV	X	X	

In these agroecological zones, the following priorities were set for the allocation of available research resources:

Agr. Zone II		Agr. Zone III		Agr. Zone IV	
Product	**%**	**Product**	**%**	**Product**	**%**
Oranges	16	Oranges	13	Coffee	20
Meat	9	Milk	10	Milk	14
Milk	9	Coffee	10	Meat	14
Coffee	8	Meat	9	Eggs	7
Sugar	8	Sugar	8		
Total	50	**Total**	50	**Total**	55

Setting Priorities by Product

When the TAC/CGIAR methodology was applied to the country information published in FAO yearbooks using the per capita availability of calories and proteins as modifiers, the following results were obtained:

Priorities set according to TAC/CGIAR methodology country data-FAO)

Product	%
Meat	14
Coffee	13
Milk	12
Bananas-Plantains	9
Potatoes	7
Total	55

As may be seen, the two exercises produced similar results in some respects: for example, beef and milk were identified as priority concerns for the allocation of available resources. There are, however, marked differences with respect to other products, as in the case of potatoes, which appear as having priority when the FAO country data are used.

As noted by the group that studied the TAC/CGIAR methodology in detail, these similarities and differences may be explained mainly by the fact that the "production value" variable carries considerable weight, independently of which modifiers are used and which relative weight is assigned to each one.

Nevertheless, it may be useful to apply the TAC/CGIAR methodology to identify the priority assigned to these products in the agroecological zones of Latin America and in the three countries selected for this exercise. This can be helpful as a criterion for selecting products with respect to which technological limitations may hinder research at the regional level.

Subregional Workshop for Planning Officials

The aforementioned criterion would not work, however, if one were to include new products that do not currently have a high production value, but which are promising given the nature of their demand or the forward economic linkages they might generate as a result of further processing or marketing. The participants at a subregional workshop for planning officials provided an opportunity to explore the possibility of including other criteria for the selection of products that might be used to begin identifying and implementing projects of regional scope.

The workshop discussion began with a presentation of the results of priority-setting exercises that were conducted at the national research institutes of the three countries selected for the case studies. It was assumed that these results reflected each institution's potential interest in participating in and contributing to a regional project.

The methodology for these national priority-setting exercises, allowing for any changes required in individual cases, consisted of estimating total economic surpluses by adding producer and consumer surpluses and deducting research and transfer costs.

Given the existing environment for agricultural research and technology transfer, this methodology was based on the assumption that local markets were isolated, and that increases in production made possible by new technologies could be absorbed at the domestic level, with resulting effect on the ratio between input-product and product-product prices.

As agricultural markets are internationalized, it becomes more difficult to estimate economic surpluses, inasmuch as relative prices are not determined by local markets, and the factors of production may have greater mobility, both within and outside the agricultural sector.

By the same token, it is not easy to estimate the opportunity cost of the resources allocated for research. The internationalization of the economy opens up other investment opportunities, such as the purchase of technology packages that are suitable to local conditions.

Economic surpluses resulting from investment in agricultural research and technology transfer were estimated, for the most part, by comparing static situations before and after technological change. This made it difficult to estimate some of the benefits resulting from externalities originating in the use of the new technology packages, for example, their different applications to other products or other regions, and their contribution to the preservation of natural resources and biological diversity.

With these exceptions, the national priority-setting exercises are bound to prove useful over the short and the medium terms, inasmuch as they will reflect the countries' most immediate needs in terms of the supply of foods and raw materials and the use of production resources, particularly land and labor.

In addition, the agricultural research services that would be responsible for most of the initial regional research projects have been designed with these priorities in mind. It is to be hoped that the structure of this supply of research services would change as a result of the regional research projects.

With the above arguments in mind, it was suggested that the following criteria should be applied in selecting a limited number of products, five at most, to be used in identifying technological and scientific limitations that might be addressed through projects of regional scope.

— Priorities for the region and for individual countries must be **consistent** in order to ensure that each national institution will take special interest in identifying, structuring, and executing a project of regional scope.

— The **main agroecological zones** existing in the three countries must be **represented** in order to ensure greater diversity in projects of regional scope, thus allowing for maximum benefits to be obtained from the subproject.

— Each study must have an impact in terms of the new general objectives of agricultural research, namely, **equity, sustainability, efficiency, and competitiveness.** This criterion will be applied in order to enhance the possibility of supplementing an institution's resources with contributions from international donors.

— The necessary **institutional capability** for setting up regional interdisciplinary groups must exist in order to ensure that the proposed project is indeed feasible.

Selection of Common Problems

Once the products that might be the subjects of regional research projects for the agricultural sector had been identified, the next step was to select problems that went beyond the scope of purely national interest.

Given the diversity of microregions and of socioeconomic conditions under which production activities are carried out, it is very difficult to forecast the adoption and the potential impact of a research study that may not be strictly in line with all the specific objectives envisaged at the beginning of each project.

For example, a project designed to develop a variety that is resistant to a given disease or pest might lead to the development of a variety that adapts well to a specific microclimate or microregion, thus upsetting the balance of relative or competitive advantages among countries.

That is why regional research projects tend to deal more with problems that can be addressed through basic research studies designed to generate know-how rather than with research aimed at adapting or generating technologies or products.

In this regard, it would seem that adaptation is a matter that must be dealt with at the national level, except in those cases in which–bearing in mind the new thrust toward economic integration–the institutions concerned clearly indicate, in advance, how costs and benefits are to distributed if and when the technology is adopted. In such cases "joint ventures" might be appropriate, especially in border regions: for example, rice projects along the border between Colombia and Venezuela, or vegetable-growing projects on the border between Colombia and Ecuador.

Another limiting factor that was taken into account in selecting common problems was that of the availability of human resources. As a result of the application of so-called "green revolution" research models, which focused on plant breeding, the most abundant and common resource in most of the research institutions is the generation and development of improved varieties, based on the manipulation of existing germ plasm banks. This model is now being questioned in several countries. As an alternative, efforts are now being made to ensure greater complementarity between studies involving molecular engineering and genetics, and the traditional plant-breeding disciplines. The idea is that molecular engineering and genetics could lead to the introduction of new varieties that would serve as sources for developing resistance to pests or diseases or for improving yields.

There are individual scientists in the region who are highly skilled in these new disciplines. They are so few, however, that even at the regional level, it is virtually impossible to develop the critical masses that would be required to generate new know-how or materials. That is why a training component is included in the proposed profiles to be submitted later on.

A similar situation occurs with regard to infrastructure. Few, if any, restrictions are imposed on experimental research efforts, and most institutions have large enough properties in the major agroecological zones. There is, however, a serious shortage of modern equipment and laboratories.

Even when a country has an adequate level of human resources and infrastructure, it may lack the leadership skills that are needed to design and implement a regional research project that will make maximum use of these resources. Projects must be identified and formulated through a highly participatory mechanism involving all the institutions concerned.

Bearing in mind the above considerations regarding selection of common problems to be studied, the research leaders of each country were actively brought into the effort. They proposed a list of issues to be addressed through regional projects to be implemented at the level of the Andean subregion.

The coordinator of the subproject analyzed these lists and submitted to the national planning officials one topic for each product that appeared to be of interest to at least two countries. Once these topics were approved, their relevance to the region as a whole was confirmed through informal contacts with the directors of existing international programs in the subregion. In addition, a review was made of the bibliographical data banks on products considered important; these data banks were supplied by specialized libraries.

Development of Project Profiles

Project profiles were developed in three stages. A scientist was appointed to take charge of work on each product study. In some cases, the persons chosen were regional leaders who had been responsible for coordinating cooperation between national centers and international institutions. Others were chosen by agreement with national planning officials.

Each scientist in charge of a study was entrusted with the task of drawing up a draft subregional project profile for the product study concerned. Two researchers from programs in neighboring countries served as reviewers: they analyzed the proposal and suggested changes in its content, scope, and methodology.

The planning officials, scientists in charge of project profiles, and leaders of international research programs then met to assess the institutional aspects of the proposals, i.e., their structure, objectives, methodology, and expected results, as well as the availability of resources in each institution and the strategy for participating institutions to work together through a clear distribution of activities.

Parallel to this meeting, a proposal for institutionalizing regional research projects was drawn up, bearing in mind the following two basic aspects:

- The logistics involved in managing the technical aspects of the project, such as coordination of activities, scientific responsibility and authorship of results, and use of products.

- The administration of and responsibility for external financial resources allocated to each project, for example, disbursements, reports, and so on.

RESULTS

Products Selected

A list of products to be considered for regional project profiles was developed at the subregional workshop for planning officials. The products were selected based on the TAC exercise and the priorities set by individual countries.

The original list, which reflected the interests of the countries used in the case studies–Colombia, Ecuador, and Venezuela–included ten products. These ten products represented three types of objectives that are usually stressed in planning agricultural research, namely, (1) the importance of the product as a component of consumer diets, (2) its significance in generating income for small farmers, and (3) its potential for generating foreign exchange.

The aforementioned priority-setting criteria were then applied to this original list of ten products, and an assessment was made of their potential impact, bearing in mind the new objectives of equity, sustainability, and competitiveness. A third group of criteria for setting priorities was also applied, that of institutional capability. This has to do with resources and the research staff's experience with interinstitutional cooperation.

This exercise brought to light some interesting facts. Under the criterion of consistency, it was found that all three countries assigned high priority to three products: meat/milk, coffee, and rice. The other products were assigned medium to high priority. It was interesting to note that chickens/eggs were assigned medium to low priority. This may be because chickens/eggs are processed from agricultural raw materials, which creates sanitary problems that are usually dealt with by laboratories in the private sector.

Under the criterion of impact relating to general objectives, cassava was the only product on which there was unanimous agreement; it was assigned high priority for the three objectives of equity, sustainability, and competitiveness. With regard to the remaining products, there were different views as to the potential impact of agricultural research in terms of the aforementioned objectives. This could mean two things:

— planning officials do not yet understand the concepts of equity, sustainability, and competitiveness well enough to include them in planning processes without regard to any theoretical or personal biases, and/or,

— the assessment may have been very limited in scope, that is, it may have taken into account only the product considered, or the region where it is grown, without regard for interactions with other variables such as job creation, efficiency in the mix of resources, potential for specialization, and so on.

The third criterion–institutional capability–was assessed at three levels: national, regional, and international. Except in the cases of meat/milk, potatoes, and corn, it was found, overall, that the institutions did not have a strong capability for organizing regional projects, even though in some cases–for example, rice–the institutions did have strong national and international ties.

As in any priority-setting exercise, final results are directly affected by the relative weight assigned to each criterion used. In this exercise, less weight was assigned to institutional capability, bearing in mind that one of the by-products of any research project of regional scope should be the strengthening of human resources through training and the identification and improved use of infrastructure through interinstitutional cooperation.

The other two criteria were assigned a relatively equal weight, in order to reflect the need to restructure research programs in the light of new paradigms of agricultural research, while at the same time ensuring continuity of activities.

Table 1 shows the results of this exercise. Products for which project profiles were developed are highlighted by an asterisk.

Table 1. Selection of products for regional agricultural research projects.

	Consistency with national priorities				Impact in terms of general objectives				Institutional capability				
Relative Weight %			40				40				20		100
Product	**C**	**E**	**V**	**WST**	**E**	**S**	**C**	**WST**	**N**	**R**	**I**	**WST**	**TOP**
1. Meat/milk	1	1	1	1.2	3	2	1	2.4	1	1	2	0.8	4.4*
2. Coffee	1	1	1	1.2	2	3	2	2.8	1	3	3	1.4	5.4
3. Ban./plant.	1	1	2	1.6	2	2	2	2.4	3	3	2	1.6	5.6
4. Potatoes	2	1	2	2.0	1	3	3	2.8	1	1	1	0.6	5.4
5. Chick./eggs	2	2	3	2.8									
6. Sugar	1	2	1	1.6	3	3	2	3.2	1	3	3	1.4	6.2
7. Rice	1	1	1	1.2	1	2	1	1.6	1	3	1	1.0	3.8*
8. Trop. fruit	1	2	2	2.0	2	1	1	1.6	3	2	2	1.4	5.0*
9. Corn	2	1	1	1.6	1	2	2	2.0	1	1	1	0.6	4.2*
10. Cassava	2	2	1	2.0	1	1	1	1.2	2	3	1	1.2	4.4*

A. Consistency with national priorities
   - C = Colombia
   - E = Ecuador
   - V = Venezuela
   - WST = Weighted subtotal

   1 = High priority
   2 = Medium priority
   3 = Low priority

B. Impact in terms of general objectives
   - E = Equity
   - S = Sustainability
   - C = Competitiveness
   - WST = Weighted subtotal

   1 = High
   2 = Medium
   3 = Low

C. Institutional capability
   - N = National
   - R = Regional
   - I = International
   - WST = Weighted subtotal

   1 = High
   2 = Medium
   3 = Low

Notes:
a) Meat/milk refers to dual-purpose livestock.
b) Tropical fruits refers to those grown for export.
c) National priorities were stated by each national planning official.
d) Economic impact and institutional capability were determined by consensus.

Source: Prepared by the author.

Topics Selected

Topics for research project profiles were chosen in two steps. First, researchers in each country were asked to prepare a list of the main limitations on the crop in question. This information was used to review problems encountered in the field, as well as alternative technologies available to researchers and to farmers. Next, the research topic was chosen with a view to solving as many problems as possible, and bearing in mind the availability of research infrastructure and methodological options in the Andean zone. The choice of topics was approved by researchers in the individual countries and, in cases where an international program was already underway, by the research leader concerned.

Table 2 shows the list of topics suggested by the researchers. This list was used as the basis for selecting the final topic, following a review of the problems encountered in each case.

Table 2. Research topics proposed by national programs.

1. Rice – Develop stable genetic resistance to *pyricularia*, *sogata*, and white leaf – Develop rice varieties at commercial levels – Incidence of weeds and deficiencies in weed-control options
2. Corn – Develop materials that are resistant to drought and acidity – Comprehensive pest control – Soil conservation management technologies
3. Cassava – Increase genetic diversity in commercial crops – High-yield improved varieties of dry materials – Comprehensive pest and disease management
4. Tropical fruits – Comprehensive pest and disease management – Study of marketing channels and market opportunities – Farming practices: planting seasons and fertilization
5. Dual-purpose livestock – Introduction and study of production performance of different breeds – Study and evaluation of parasitic diseases – Restriction on production of forage under drought conditions

Source: Prepared by the author.

Rice

The problems faced by rice producers in the Andean zone have to do with competitiveness vis-à-vis foreign sources of supply. In essence, the countries in the subregion are at a disadvantage, inasmuch as high production costs limit the possibilities for increasing production. This problem could be solved by developing, generating, and multiplying commercial varieties with special characteristics, bearing in mind the existing constraints on production and local demand.

Traditionally, the national rice research program in each of the five countries of the region has been responsible for producing such commercial varieties. The strategy applied by these national programs has been to maintain and manage germ plasm banks, with assistance from the international programs of IRRI and CIAT.

In all the countries, the rice growers have been receiving the commercial varieties on a regular basis. The problem lies in the fact that the useful life of the individual varieties is very short. An analysis of the data has shown that the average useful life of a commercial variety delivered by a national program has decreased from five to two years. As far as research per se is concerned, this means that the cost-benefit ratio of investments for the development of new varieties is very low, and that the germ plasm banks themselves are losing the potential for innovation.

Researchers attribute the shortening of the useful life of commercial varieties to the effect of the disease known as *pyricularia*, which is produced by a mutant pathogen. In practice, no variety is immune to the pathogen; researchers are merely seeking to develop more resistant varieties.

At the same time, other fields of biogenetic research have developed methodologies for identifying and marking genes that could be used to identify those "pathotypes" that are responsible for the appearance of *pyricularia* in rice crops. A technique for accomplishing this has already been developed in the laboratory, but it has not been tested in the field.

By selecting the identification of *pyricularia* pathotypes at the field level as a research topic, the Andean zone subproject seeks to fill the gap between international programs that generate basic know-how, and national programs, which are geared toward applied research.

Such information as is generated at the field level will be useful to the national programs, inasmuch as it will enable them to improve their selection criteria for the production of new commercial varieties.

Corn

The problems encountered in growing corn have to do with the environment in which the crop is produced. Nearly 80% of the area planted in corn in the Andean zone is not irrigated; this means that, as is the case with all rain-fed crops, it is vulnerable to climate changes.

The shortage of water and, in many cases, the complete absence thereof, affects yields and production costs. This, in turn, has a direct impact on competitiveness and potential income, a problem that particularly affects small farmers.

In considering this problem, researchers agreed that the critical factor affecting corn crops is the shortage of water during the blossoming season. The solution would be to improve the plant's physiological performance at this critical stage. National programs have developed genetic materials that meet these requirements, but they have been hindered by logistical problems. In order to develop drought-resistant materials, it is important that studies be carried out in specific environments where water levels can be strictly monitored. In other words, the experiments must be conducted in an environment of minimal rainfall.

Another logistical problem has to do with germ plasm banks, which are used as a source for the generation of new materials. International programs have already identified, selected, and classified materials that are suitable for research on drought-resistant species.

Finally, once the materials have been developed, they must be tested for adaptability to different field conditions. This entails conducting a large number of tests for the many different zones where corn is produced.

The proposed research on drought-resistant species would entail collaboration among the different national programs of the region, and taking advantage of the ideal field conditions in Ecuador and Peru, where rainfall is low. This would make it possible to produce materials and to enable other national programs to do such further testing as may be necessary. International, regional, and national activities would be linked through the use of the advanced materials developed by CIMMYT.

Cassava

The problems involved in growing cassava are twofold. At the field level, farmers in each of the regions tend to use only one or two varieties. As a result, there is not much genetic diversity and the potential for pest and disease infestation is high. At the laboratory level, however, there is a large collection of materials that have been identified and classified according to genetic types and potential uses in different markets.

One limiting factor that is common to all the cassava-producing regions of the Andean zone is the production system. At the level of small-scale farming, cassava is but one component of the production system; hence, any transfer of technology is bound to affect the overall balance of agricultural production. The market for the production of a particular region may also impose limitations. There are different markets for bitter cassava, for intermediate products (such as cassava starch), and for processed products (such as dry cassava for animal feed). Each market requires a very distinct variety of cassava.

The topic on introduction of genetic diversity in production systems was identified through an exercise in participatory methodology. In essence, the idea is to achieve two objectives simultaneously, that is, the introduction of new materials and varieties on farms, and the training of technology transfer staff in the use of participatory methodology. Both outputs can be used independently by national programs.

Tropical fruits

Research on tropical fruits will be somewhat hindered by the intense competition among the countries, as each one seeks to identify, develop, and maintain its own international markets. The problem is further complicated by the fact that research most directly benefits private producers at the middle- and high-income levels, who might be expected to initiate studies themselves.

As far as the State is concerned, there are certain problems in implementing policies aimed at diversifying agricultural exports as a means of enabling the Andean countries to generate investment and job opportunities. Most studies show that the fruit-growing sector has the greatest potential for growth, given the characteristics of the final demand, such as high income elasticity. The main constraint on fruit exports is the health of the products per se.

In reviewing the problems affecting this sector, it was found that the main one was the lack of basic information needed to design policies and actions aimed at improving plant health. There is an extremely wide range of aspects that need to be studied, considering the many different products, regions, pests, and diseases that are involved. Most of the countries, as well as many public and private groups in individual countries, are carrying out isolated research studies. These studies are mainly designed to solve specific problems, such as the application of agrochemicals or postharvest treatment, and thus are not conducive to finding a definitive solution to the overall problem.

The objective of the study proposed by the Andean zone would be to generate basic information on quarantine management that would be valid for a number of export fruits. Such a study could be used in training researchers in the subregion. This would also have implications for the distribution of tasks among the countries, as well as for the management of the information produced.

It is envisaged that the main function of the national research institutes would be to coordinate the work of private-sector groups, with a view to facilitating regional integration.

Meat and milk

In the Andean zone, meat and milk were assigned high priority in every case. There are many possible topics for research, but the national researchers narrowed the range down to three main areas: breeding, health, and nutrition. Nutrition is considered to be of paramount importance by the national research centers, for two reasons. First, breeding and animal health problems are being adequately addressed by the private sector through producer associations and commercial laboratories. Second, nutrition research can benefit different groups of producers, regardless of the scale of their operations.

With regard to nutrition, one of the main problems faced by stock growers throughout the Andean zone, but particularly by producers of dual-purpose livestock, has to do with the supply of nutrients during dry seasons, when both meat and milk production fall drastically.

There are different ways to approach this problem, but some of the best results have been obtained through the introduction and adaptation of drought-resistant forage, both grass and legumes. International programs, in particular, have made it possible to collect, identify, and classify a variety of materials. International testing of such materials has enabled national programs to develop germ plasm banks of their own.

The discussion on these issues brought to light three areas of weakness in existing efforts to introduce and adapt forage species in regions where dual-purpose livestock is produced. First, national programs have not followed through with the task of adapting and transferring results to the farm level. Second, and specifically in the case of dual-purpose livestock, not all the producing regions have been covered. International programs have focused on acid savanna soils, while much of the meat and milk are produced in regions with different types of soils. Third, weaknesses have been found at the final stage of the process–the management and use of forage in animal diets.

Hence, in selecting the topic on production of forage species for dry-season production, the subproject aims to make use of materials that have already been identified at the Andean zone level, to expand on and increase testing in regions–within each country–that produce dual-purpose livestock, and to conduct tests relating to animal diets.

Project Profiles Identified

Once the working group had identified the methodology to be followed and had selected the products and topics to be studied, a leader and two reviewers were assigned to draw up the relevant research project profiles. At the final meeting, the profiles were approved, bearing in mind both the institutional and the technical standpoints, by the national planning officials and by the leaders of international programs at CIAT, CIMMYT, and the Andean Fruit Center.

The discussions at which the various draft project profiles were evaluated allowed for explicit suggestions to be made on how to fill the gaps or breaks in the technology generation process, which begins with basic research at international centers and culminates with the adoption of results by farmers.

Essentially, the regional projects will focus on research aimed at facilitating intermediate adaptations. The aim is to produce two types of outputs, both of which will be available to the national programs. Firstly, genetic materials or methodologies will be developed for use by individual national programs, according to their needs and specific objectives. Secondly, researchers participating in the project will receive training so that they may remain with the programs and ensure the continuity of work done at the national level.

One aspect to be borne in mind is the duration of the projects, usually about four years. This is important because, on the one hand, the scientific staff must be able to remain for the duration of the study and, on the other hand, the projects must be included, on a yearly basis, in the schedule of activities of the national programs. In other words, researchers must be prepared to commit themselves to the regional project concerned for its entire duration.

The projects are estimated to have an average cost of US$400,000, or US$100,000 per year. It is important to remember, however, that the financial estimates include the contributions to be made by national programs in terms of infrastructure, services, and staff. This is a good indication that they are quite likely to be implemented.

The five profiles that have been drawn up are summarized in the following tables.

Table 3. Project summary for rice.

Title:	Study of the Evolution of Pathotypes of *Pyricularia grisea sacc.*
Leader:	Anibal L. Tapiero, ICA–Colombia
Reviewers:	F. Andrade, INIAP–Ecuador A. Salle, FONAIAP–Venezuela
Duration:	4 years
Budget:	US$368,550
Outputs:	1. Staff training 2. Identification of pathotypes 3. Projects on generation of resistant varieties

Source: Prepared by the author.

Table 4. Project summary for corn.

Title:	Development of Drought-tolerant Hard-corn Germ Plasm
Leader:	Mario Caviedes C., INIAP–Ecuador
Reviewers:	A. Navas, ICA–Colombia F. San Vicente, FONAIAP–Venezuela
Duration:	5 years
Budget:	US$274,000
Outputs:	1. Drought-tolerant varieties (3) 2. Evaluation and selection methodologies 3. Staff training

Source: Prepared by the author.

Table 5. Project summary for dual-purpose livestock.

Title:	Introduction and Evaluation of Forage Species in Different Ecosystems
Leader:	Jesus Faria Marmol, FONAIAP–Venezuela
Reviewers:	G. Martinez, ICA–Colombia J. Rivadeneira, INIAP–Ecuador
Duration:	5 years
Budget:	US$742,320
Outputs:	1. Introduction and evaluation of forage species on isohyperthermic savannas 2. Introduction and evaluation of forage species on floodable savannas 3. Introduction and evaluation of forage species in dry zones with medium- to low-fertility soils 4. Multiplication of promising germ plasm

Source: Prepared by the author.

Table 6. Project summary for fruits.

Title:	Quarantine Management of Export Fruits in the Andean Subregion
Leader:	Nancy Boscan, FONAIAP–Venezuela
Reviewers:	J. C. Toro, ICA–Colombia J. Mendoza, INIAP–Ecuador
Duration:	3 years
Budget:	US$372,000
Outputs:	1. Development of quarantine management technologies for papaya, tree tomatoes, *lulo,* and pineapple 2. Transfer of existing mango quarantine techniques and of those developed by the project 3. Training of Andean zone researchers in quarantine techniques

Source: Prepared by the author.

Table 7. Project summary for cassava.

Title:	Increase and Improvement of Genetic Diversity in Cassava Production Systems
Leader:	Antonio J. Lopez, ICA–Colombia
Reviewers:	F. Hinostroza, INIAP–Ecuador E. Velasquez, FONAIAP–Venezuela
Duration:	5 years
Budget:	US$300,300
Outputs:	1. Varieties with different ripening cycles for different uses 2. Model for introducing genetic diversity on farms producing cassava 3. Feedback on selection parameters in national programs 4. Training materials for dissemination of methodologies

Source: Prepared by the author.

PROPOSAL FOR INSTITUTIONALIZING THE IICA/IDB PROJECT ON RESEARCH PRIORITIES

The following proposal is based on the assumption that the aforementioned projects have been approved by research authorities in the region, as well as by the Inter-American Development Bank (IDB). This proposal is, therefore, intended to provide for the execution of the aforementioned projects. In addition, the idea is to take advantage of the experience gained in the subregion with regard to the administration and coordination of such projects by IICA and, especially, by PROCIANDINO. Following is a description of the units involved in project coordination, administration, execution, and evaluation, and of the way they relate to each other.

Units and Their Duties

There would be three levels of responsibility: senior administration, coordination and advisory services, and operations.

High-level management

High-level management would be provided by the IDB, as the main funding agency; the bank would also provide overall monitoring and evaluation. Other funding agencies that might become interested in the project would eventually be included at this level.

PROCIANDINO and local IICA offices would be responsible for overall coordination of the project and management of resources, especially financial and logistical resources. They would also design and operate a system for monitoring and evaluating the activities of individual enterprises.

Coordination and advisory services

Each of the participating NARIs would need to set up a unit to be in charge of **overall coordination** of the work carried out in each country. This unit would also manage the resources allocated to the country concerned, and would coordinate the monitoring and evaluation activities carried out by the research projects. In the individual NARIs, these tasks would be performed by the directorate of research and the office or directorate of planning. The planning office would also be responsible for ensuring that project activities are included as part of the regular program of work of the NARI.

The general coordination offices in the NARIs would, in turn, maintain strong ties and coordination with PROCIANDINO and the local IICA office.

The international centers operating in the region (CIAT and CIMMYT), which have a mandate to work with four of the five products concerned, should also be taken into account. In order to avoid duplication, actions should be coordinated with these centers, which may also provide advisory services.

Operations

The **subregional technical coordination offices** (one for each product) that would be responsible for the technical supervision of research activities, would work at the operations level. Their main duties would be to identify new problems, draw up and review projects, implement projects in the country concerned, and be responsible for coordinating and monitoring technical activities in the other countries. These units would also be responsible for evaluating all research on each product at the subregional level. They would work in coordination with PROCIANDINO, local IICA offices, and the international centers.

There would be a **local technical coordination office** in each of the remaining countries (the countries other than the one where the subregional technical coordination office is located). These local offices would carry out activities pertaining to diagnosis, formulation, execution, coordination, monitoring, and evaluation at the local level. The teams of local researchers would be staff members of these local coordination offices, which would also coordinate their work with the local IICA office.

A **technical committee** would be appointed for each of the five product studies. These committees would decide on matters relating to their particular fields of expertise. The technical committee would be made up of the subregional technical coordinator (project leader), the national leaders or technical coordinators for each project, and representatives of the international centers.

The different units and their duties are shown in Table 8.

CONCLUSIONS

Subregional Priority-setting Exercise

It is worth pointing out that this study represents an effort to make up for the absence of a framework of regional priorities. PROCIANDINO, a cooperative effort of the countries of the region, is the only program that comes close to providing such a framework. PROCIANDINO, however, cannot be considered a substitute for a systematic effort to identify and agree on shared priorities, particularly in view of the changes that have taken place in the environment and the objectives of current research. Hence, one of the first con-

Table 8. IICA-IDB-Priorities project.

Level	Unit	Duties
Administration	IDB	Funding Monitoring Evaluation
	PROCIANDINO	General coordination Administration
	IICA Offices in member countries (3)	Monitoring Evaluation
Coordination and Advisory Services	NARI (3)	General coordination Country coordination Country administration Monitoring Evaluation
	International centers	Advisory services
Operations	Subregional technical coordination (5)	Diagnosis of problems Project formulation Execution projects own country Coordinating and monitoring projects in other countries Evaluation of subregional projects
	Local tech. coord. (10) (2 per product)	Local diagnosis Local formulation Local execution Local coordination Local evaluation
	Local researchers (?)	Execution Monitoring Evaluation

Note: Numbers in parentheses indicate the number of units.

Source: Prepared by the author.

clusions to be drawn from this subproject is that there is a need for a subregional priority-setting exercise. The objectives, methodology, and implementation of such an exercise would be different from those of efforts made at the national level. In this regard, the following aspects should be borne in mind:

— **The subregional scenarios in which the research and transfer of agricultural technology are to carried out.** These are influenced by factors such as the following:

  - The new role of the agriculture sector, which must now compete with other sectors for production resources–especially capital and manpower–by means of relative remuneration. Consideration should also be given to eliminating biases, such as import taxes and discriminatory relative prices, which have limited the growth of agriculture.

  - The different levels of subregional integration, which in theory should allow for specialization based on relative or competitive advantages and market growth, and thus would allow for the adoption of technologies offering economies of scale.

  - Common trade policies with respect to third parties. These have a direct bearing on subsidy structures and distortions on the international market for agricultural products. The assumption underlying this statement is that the national governments will, to some extent, use the availability of subsidized raw materials and foods to measure the impact of policies on certain variables at the macro level, particularly employment, inflation, fiscal deficit, and GDP growth rate.

— **The general objectives to which the research and transfer strategy is supposed to contribute,** including food security for the region and/or the strengthening of agrofood chains.

  - In the first case, that of food security, the emphasis would be on improving the production of primary goods that are in demand especially among the low-income strata, bearing in mind factors such as population growth and the deterioration of indicators of social well-being, particularly nutrition.

  - In the second case, that of strengthening of agrofood chains, the emphasis of research and technology transfer would be on improving quality and on the processing of raw materials. This objective is predicated on the need to gain access to markets where purchasing power is high, thus generating employment and profitable investment opportunities.

— **The new criteria for evaluating and setting priorities at the national level among different alternatives, such as equity, sustainability, productivity, and competitiveness, cannot easily be aggregated and transferred to the subregional level.** The priority-setting exercise must therefore make a theoretical and methodological contribution toward such an effort.

- The greatest problem that must be addressed in a subregional priority-setting exercise is that of the great diversity of agricultural sectors that exist in the different countries. Some countries, such as Colombia, have a tradition of substantially self-sufficient agriculture, while others, such as Venezuela, have relied heavily on imports for their supplies.

— **In light of the above, the TAC suggestion that regional priorities should be set according to homogeneous agroecological zones appears quite reasonable.** The main problems involved in adopting this proposal, however, are the absence of clear criteria for identifying internationally homogeneous agroecological zones and the lack of readily available information to facilitate the task. In fact, this issue should be assigned top priority as a topic for a subregional research project.

— **The actors and the structure of research in the agricultural sciences have changed substantially.**

- The public sector no longer plays the predominant role it used to; private agents now often take the initiative in funding and carrying out research projects.

- The objectives of the national agricultural research institutions (NARIs) are changing, and the focus is now on generating know-how, conducting basic research, and promoting equity and sustainability.

- With the above changes, there is a tendency to move away from a single-institution structure toward a more complex structure of national research and transfer systems, in which the end user of production and/or processing techniques is expected to have the last word on how public resources are allocated.

Assessment of Available Research Resources

The second conclusion that may be reached at the end of this subproject has to do with the need to assess, at the subregional level, the research resources presently available in the different countries and institutions. This assessment, which was begun under the IDB/IICA project, must meet two immediate needs:

— It must provide a basis for proceeding immediately to design research and transfer projects, with a view to improving, if not maximizing, the use of human, physical, and financial resources.

— It must provide a frame of reference for analyzing potential investments aimed at improving the quantity and quality of regional research resources, bearing in mind the need to make optimum use of existing resources.

- In the area of human resources, training should focus on disciplines that will supplement existing resources, in order to create a critical mass at the upper echelons and thus generate new know-how that can be appropriated across the board.

- As regards investments in physical resources, the problem is to determine where they should be located and the degree to which other countries should participate. This decision has more political than technical implications, the arguments relating to complementarity and development being equally valid.

- As regards financial resources, the working hypothesis that has recently gained the widest acceptance is the idea that the problem is not merely one of availability, but also of allocation of resources. At the national level, expenditures have been scattered among a number of activities, thus limiting their actual impact. By allowing for an integration of efforts, regional projects can help eliminate this problem.

- Experience has shown that certain regions have a number of features that facilitate research. National priority-setting systems have not explicitly considered environment as a resource. Using the availability of this resource as a criterion for allocation could help solve part of the problems involved in distributing investments among physical and financial resources.

Individual Advantages and Possible Distribution of Tasks

The methodology applied to this subproject has shown that it is possible, by bringing together administrators and scientists, to identify the unique advantages of each national group and then distribute tasks taking into account these advantages.

The effort was greatly facilitated when work had already been done at the regional level, as in the case of the networks. In principle, these networks facilitate communications and allow researchers to assess the situation on a case-by-case basis.

Nevertheless, not every product or every participant needs to adjust to this work plan. With products that have a longstanding tradition of research, such as staple foods, it is feasible to work through a network. However, with new products, such as export crops, new forms of association must be identified, and greater weight may sometimes be assigned to institutions or to individuals, as the case may be. When individuals are concerned, it would be easier to work at the level of disciplines–entomology, for example–than at the level of production-export enterprises.

It appears from all of the above that at a later stage it would be worthwhile to study the possibility of developing institutional mechanisms and forms of association that would allow for cooperative research in new areas. Such efforts should, in principle, build on and improve on existing institutional systems, such as PROCIANDINO.

Institutionalization and Administration

It is evident from the above that subregional research projects need to be institutionalized. Indeed, in order to facilitate comprehensive planning, monitoring, and evaluation at the subregional level, an institutional scheme must be developed that will guarantee the following:

— The continuity of planning and priority-setting efforts, with a view to ensuring that projects have both stability and flexibility. Stability is particularly important with regard to the senior staff of participating institutions. Flexibility must be maintained when it comes to developing multilateral and bilateral agreements and implementing changes in macro and sectoral policies over the medium and long term.

— The monitoring of agreed work plans in order to find solutions for short-term problems that hinder or prevent the implementation of plans.

— An ongoing evaluation of progress and results as a mechanism for selling the regional research strategy. Evaluation must be viewed as a means of supporting and supplementing national and/or local programs and projects (e.g., staff training, availability of technologies and materials)

The methodology applied to the subproject brought together institutions that work at different levels, such as national centers (ICA, INIAP, FONAIAP), research networks (PROCIANDINO), international centers (CIAT, CIMMYT), and private institutions (Andean Fruit Center). These institutions, working together, suggested the following ideas for institutionalizing subregional research:

— They identified three levels of responsibility within each regional project to be implemented. The first would be high-level management, at which decisions would be made for managing, monitoring, and evaluating resources that are available for the research project. The funding institutions, PROCIANDINO and the local IICA offices would act at this level.

— The second level would be that of coordination and advisory services. This responsibility would be assigned directly to the national research institutes that participate in each regional research project. One of the reasons for doing this would be to ensure that activities pertaining to the regional project are included in the regular program of work of each national institution.

— Actual execution of activities at the operational level would be assigned to a subregional technical coordination office. Coordination would be directed by a regional technical committee made up of leaders of the national research projects participating in the project. If an international center is actively involved in the implementation of certain project activities, it would also be represented on the regional technical committee.

Chapter 5

AGRICULTURAL RESEARCH PRIORITIES IN CENTRAL AMERICA

Hector Medina Castro

CONTENTS

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INTRODUCTION

The main purpose of this study is to show the agricultural research priorities (ARPs), by product, that have been identified in the Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama). These priorities were identified in each country during the period 1990-92 (Medina Castro 1990, 1991b, 1991c, 1991d, 1992a, 1992b).

The study is directed at researchers, administrators, professionals, and students who are involved in policy design, planning, and allocation of resources for agricultural research (AR).

The first section outlines the basic elements analyzed and sets the findings on priorities in the proper context. The methodology used in each country is then described in detail, and the findings are shown.

Defining Priorities

A number of different methods can be used for setting priorities and allocating resources among different research options (Medina Castro 1991a). It is usually easier to set priorities than to assign resources; at the same time, priorities must be set before resources can be allocated. Priority setting involves establishing an order of precedence; resource allocation is a multidimensional effort, inasmuch as it calls for different types of resources (human, physical, and operational) to be distributed among different research options.

National research systems are organized differently in different countries, and the availability and reliability of information varies from one Central American nation to another. Therefore, a priority-setting method was chosen that would be general and flexible, so that it could be applied in all the countries, especially those in which very little information from secondary sources is available. The choice of method was made according to the results obtained in each country over a period of two to three weeks. The scoring method of priority setting was chosen because it is simple and easy to implement, and it takes into account the objectives pursued in the agricultural policies of the countries considered.

In this context, priority setting is defined as the process of ranking different agricultural research options according to their importance, in order to provide information that will allow for resources to be allocated in such a way as to improve the well-being of the population.

Context

Toward the late 1980s and the early 1990s, the Central American countries made adjustments in their economies that were designed to enable them to come out of the crisis they were undergoing, particularly after the oil shock of the 1970s, which had led to a deterioration of the terms of trade (e.g., the drop in the international prices of commodities, especially coffee). This crisis had been aggravated by the countries' external indebtedness and the high interest rates prevailing in the international financial markets in the early 1980s.

The crisis not only caused a decline in the gross domestic product (GDP); it also exacerbated existing economic inequalities (Stonich 1991). To a certain extent, it brought to light the fact that the model based on "inward growth"–increasing domestic demand and promoting industrialization through import substitution–was obsolete. Essentially, the recent adjustment programs were geared toward completely opening the country up to international trade, deregulating prices and privatizing the economy (Fallas and Rivera 1988).

In Central America, the "success of adjustment" has been measured by the growth of nontraditional exports, which shows the extent to which the countries have succeeded in adjusting their economic structure in order to diversify their exports and use their comparative advantages (Irvin 1991), thus promoting a reorientation of the economy toward "outward growth." The countries that have been most successful in this effort are Costa Rica and Honduras.

The promotion of nontraditional agricultural exports is a central component of this economic growth strategy. In Central America, traditional export commodities are bananas, coffee, sugarcane, and beef.

It is worth mentioning that macroeconomic adjustment policies affect the lowest income groups in society (Pinstrup-Andersen 1990). In Latin America, the lowest income groups have suffered the most during the initial stage of adjustment, when the economy must be stabilized through measures designed to lay the foundations for growth, such as wage controls and subsidy reduction (French-Davis 1989).

In Central America, there are cases in which even during a later stage of adjustment–the stage of growth based on an increase in exports, especially nontraditional agricultural products–small farmers have been displaced in the process of expanding the production of nontraditional export commodities (NTE). This process also has a negative effect on natural resources and the environment (Stonich 1991). Thus, certain growth patterns are not neutral in terms of equity, natural resources, and the environment.

In light of the above, it is understandable that the attainment of economic growth with social justice and natural resource conservation are included among the stated objectives of the agricultural development plans of most of the governments of the region (Costa Rica, Guatemala, Nicaragua, and Panama). Hence, in the priority-setting exercises conducted in the Central American countries, the goals of efficiency, equity, and sustainability were chosen as guidelines for identifying priorities.

National Agricultural Research Systems

When identifying national agricultural research priorities and research options by product, as in this study, it is helpful to take the following steps: (a) define a national agricultural research system; (b) analyze its "structure," and (c) tie that structure in with the ARPs that have been identified.

In general terms, a national research and technology transfer system is made up of national institutions, both public and private, that generate or transfer agricultural technology in the country. These institutions, in turn, make up a subsystem, the National Agricultural Research System (NARS). The system includes different types of institutions in one or more ministries, mixed or parastate agencies, and university-level schools of agronomy, as well as in the private agricultural sector.

The structure of a NARS or of one of its components includes elements such as the number and size of the institutions that belong to it, the sector to which the institutions belong (public, private, or mixed), their fields of action (e.g., stages in the production sector, disciplines, products on which research is done) and the linkages (vertical or horizontal) among them.

The macroeconomic adjustment measures that have been implemented, particularly those aimed at reducing the size of government, have brought about rapid changes in the structure of institutions in Central America, as they redefine their size, their functions, and their sphere of action. At the same time, new institutions have been making their appearance, usually in the private sector.

In the case of the Central American countries, it is particularly pertinent to note the structure of the institutions that are conducting research on final products and on production categories. This structure is different in each country. In Panama (1990), for example, there appears to be a monopoly: fundamentally, almost all research on the categories under consideration is carried out by a single state institution. In the case of Nicaragua (1991), research on final products is done by several institutions.

In interpreting the findings on priorities by product at the national level, it is important to bear in mind the structure of the NARS institutions that do research on final products. If the structure is monopolistic, for example, priority-setting will consist of ranking the different categories for purposes of allocating research resources within the institution concerned. If the structure is divided, priorities will be set among the different institutions and, occasionally or implicitly, those same institutions will also be ranked according to priority.

Usefulness and Limitations of the Method Chosen

The order of priorities established by using the scoring method is useful for purposes of deciding to which products research resources should be directed and/or for which products resources should be sought, in order to attain established objectives. This method, however, only allows for priorities to be set among different research options. The ARPs established under this system do not automatically indicate the order in which resources should be allocated among the different options, let alone the magnitude of such resources.

Giving high priority to a certain product, for example, does not necessarily mean that a high level of research resources will be assigned to it, inasmuch as other factors, such as supply of and demand for technology must also be considered. Indeed, a product may have high priority and a high supply of technology, but not much demand for technology. This would mean that allocating more research resources to that product than to others could be economically inefficient, inasmuch as the social benefit would be greater if part of the resources were directed toward research on products that have lower priority but a greater supply of and demand for technology.

Even so, the methodology used in this study, and the results obtained, represent the first step in a process that is designed to provide useful information for purposes of decision making on the allocation of research resources.

METHODOLOGY

In the early 1990s, most of the governments of the Central American region had drawn up elaborate agricultural development plans, with a view to achieving sustainable growth in production while ensuring greater equity and preserving natural resources. In light of the above, the model proposed for setting research priorities by product includes three objectives that serve as guidelines, namely efficiency, equity, and sustainability. These are defined as follows:

— **Efficiency:** Agricultural production is increased or production or research costs are reduced.

— **Equity:** The well-being of low-income groups is improved.

— **Environmental sustainability:** The environment is protected and natural resources are preserved.

The three objectives are independent, inasmuch as action aimed at achieving one of them does not necessarily help achieve the other two; in fact, they may sometimes be in conflict with each other (Daly 1991).

There are patterns of growth in which production is increased at the expense of equity. As pointed out in the theory of induced innovation (Bingswagner and Ruttan 1978), for example, under certain circumstances, an increase in agricultural production through intensive mechanization may reduce the use of unskilled labor, thus lowering the income of certain marginal groups. Similarly, certain agrarian reform projects that entail distributing forest areas to landless farmers might improve the economic position of low-income groups, thus helping to improve the distribution of income, but would increase deforestation and have a negative impact on the ecosystem. This does not mean that whenever economic efficiency is improved, equity deteriorates, or that equity improves at the expense of sustainability; rather, it means that in some cases, actions aimed at meeting one of the three objectives may have a negative effect in terms of the others. Consequently, in considering priority-setting policies, it is important to consider the potential trade-offs among objectives.

As indicated above, the scoring method was chosen for the priority-setting exercises with which this report is concerned. Not only is this method simple and easy to apply, but it allows for the participation of personnel involved in research and transfer activities, as well as directors, administrators, and planners concerned with agricultural research, thus ensuring that the findings will be credible. The Lotus 123 computer scoring program was also used to establish the ARPs (Medina Castro 1992c).

Identification of Research Priorities

Scoring models have been widely used in Latin America (Gomez Quiroga *et al.* 1977; Norton and Pardey 1987) to identify agricultural research priorities by product at the national or regional level. Scoring models generally use two types of variables. One has to do with the economic efficiency objective (level of exports and imports, level of production, future demand). The other has to do with the equity objective (levels of calories and proteins provided by the diet, number of small farmers).

Under this approach, which is based on Norton and Pardey (1987), the application of previous scoring models is extended to add the income-security objective and include variables pertaining to research efficiency. The Norton and Pardey model is modified somewhat, however, as income security is replaced by the sustainability objective. In the model developed by these authors, each objective is represented by at least one criterion, and each criterion, in turn, is represented by one or more variables.

Variables Considered in Setting Priorities

The first objective –economic efficiency– includes three types of criteria:

1. Importance of the product, which in turn is associated with the following:

   a. Value of production. The higher the value, the more important the product.

   b. Value of the volume of international trade (measured by the value of imports plus the value of exports). Greater importance was assigned to products with a higher value.

c. Anticipated change in demand during the next five years. Greater importance was assigned to products that are expected to show (proportionally) increased demand.

d. Comparative advantage. Since a country's income will increase if it makes an effort to promote those exports that it is better equipped to produce with its own resources, a higher ranking was assigned to products that have a greater comparative advantage, this being estimated by the domestic-cost-of-resources (DCR) coefficient, when available (see definition of DCR in Scandizzo and Bruce 1980).

2. Research potential, associated with the following:

   a. Seriousness of problems to be researched. Greater importance was assigned to products that had the most serious problems (in the opinion of the researchers).

   b. Research potential (in terms of anticipated increase in yields), as assessed by the researchers. Greater importance was assigned to products having greater potential.

3. Efficiency in the use of research resources, associated with the following:

   a. Research experience. Since the cost of research is reduced, *ceteris paribus,* as experience is gained, higher priority was assigned to products on which more researcher-years of experience had already been accumulated.

   b. Flow of information to and from international research centers. Higher priority was assigned to products on which there was a greater flow of information to and from international centers with regard to the research being conducted.

   c. Private-sector incentives to conduct research on a given product. In order to assign resources in the public sector, higher priority was assigned to those products on which the private sector was offering fewer incentives for research.

With regard to the second objective–equity–the distributive impact of research results was considered, according to the following variables, associated mainly with low-income groups:

a. Contribution in calories (average) to the daily diet.

b. Contribution in proteins (average) to the daily diet.

c. Level of self-consumption on the part of producers. The importance of products increases as the level of self-consumption of the "typical" farmer increases.

d. Number of farmers. The greater the number of farmers growing a particular product, the more important the product.

e. Impact on resource utilization (job creation). Higher priority was assigned to products involving the use of labor-intensive technology (or technology that is less likely to reduce the use of manpower). In the case of El Salvador, where land is a critically scarce resource, high priority was assigned to categories involving the use of technologies that save on the use of land.

The sustainability objective was associated with the potential environmental impact of the research, determined as a consequence of the adoption of the technology in question, in the opinion of the researchers interviewed. Thus, low priority was assigned to categories that involve the use of technologies which are more likely to harm the environment, such as those that call for intensive use of agrochemicals.

Figure 1 shows the relationship between variables and objectives. Except in the case of sustainability, the variables described were used to identify ARPs by product in El Salvador, Nicaragua, and Guatemala, while they were all used in the cases of Costa Rica, Panama, and Honduras.

Objectives	**Efficiency**		**Equity**		**Sustainability**
CRITERIA	Importance of product	Research potential	Efficiency AR resources	Distribution of impacts	Impact on environment
VARIABLES	a. Value of production	a. Estimates by scientists	a. Research experience	a. Contrib. calories	a. Environmental impact of adopting technology
	b. Value of int'l. trade imports + exports	b. Seriousness of problems	b. Flow of information to and from int'l. centers	b. Contrib. proteins	
	c. Future demand	c. Anticipated increase in yield	c. Private sect. incentives	c. Self-consumption	
	d. Comparative advantage			d. No. of farmers	
				e. Impact on resources	

Figure 1. Conceptual elements of the scoring model for identifying priorities by product.

Source: Prepared by the author based on Norton and Pardey 1987.

Determining Priorities

The list of products to which priority must be assigned is different in each country. The choice was made by the researchers and local administrators. In order to identify priorities, the variables described above were divided into quantitative variables and qualitative variables, as shown in Table 1.

Table 1. Variables for identifying research priorities.

Quantitative	Qualitative
1. Value of production	10. Seriousness of problems to be solved through research
2. Value for international trade	11. Private sector incentives
3. Anticipated change in demand	12. Impact of technology on environment
4. Comparative advantage	13. Use of resources (manpower)
5. Research experience	14. Flow of information to and from international centers
6. Number of farmers	15. Research potential (anticipated increase in yields)
7. Level of self-consumption	
8. Calories provided in average daily diet	
9. Proteins provided in average daily diet	

Source: Prepared by the author.

Given the list of n products to which priority must be assigned, for each quantitative variable the products were ranked (from 1st to nth) according to the value of the variable. At the same time, each product was assigned a partial score according to the rank it was assigned for the variable: first place was scored as n points, second place as n-1 points, and so forth.

In order to determine the importance of products according to qualitative variables, the researchers working at institutions were interviewed. They were asked to express their views on all the research categories being considered. For each qualitative variable, they were asked to set a value (2 = high, 1 = low, 0 = none) for each product. The type of response was the value assigned to the product for each of the qualitative variables.

A partial score for a product in each qualitative variable was determined in much the same way as the partial score for the quantitative variables. Based on this figure, a score for each "i" product was determined, according to the following formula:

1) $$P_i = \sum_{j=1}^{m} W_j * X_{ij},\ i = 1, 2, \ldots, n$$

with $\sum_{j=1}^{m} Wj = 1$; where

W_j = the weighting factor or weight of variable j.
X_{ij} = partial score of product i for variable j.
j = $1,...,m$; $i = 1,...,n$.

According to formula (a), the score assigned to each product depends, among other things, on the values of the weighting factors, which determine the weight or importance of each variable.

In order to calculate the weighting factors for each country, interviews were conducted with researchers and administrators involved in agricultural research. Each person interviewed was asked: (a) to assign a weighting factor (in percentage terms) to each of the quantitative variables, adding up to a total of 100%; (b) to assign a weight to the qualitative variables, adding up to 100%; and (c) to assign an overall percentage to the quantitative variables, and an overall percentage to the qualitative factors, adding up to 100%. Finally, the ranking of each qualitative variable was obtained by multiplying its average by the average of the overall percentage of the quantitative variables. A similar procedure was followed to determine the weight of the qualitative variables.

The scoring program applied to the information obtained identifies the ARPs according to formula a and ranks (in descending order) the categories, according to the total score obtained.

The scoring model adopted, and the corresponding software, made it possible in some countries (Costa Rica, Honduras, and Panama) to consider additional sets of weighting factors, called scenarios, in order to identify changes in priorities as a result of a change in the emphasis given to a particular objective, which makes it possible to analyze exchanges between independent objectives. These exchanges are perceived when there is a change in the weights of variables associated with one of the objectives so as to preserve the zero figure.

For example, if the weights of the variables associated with the equity objective (Fig. 1) are increased, the weights of the remaining variables decrease or remain constant, in order to ensure that the sum of the weights of all of them is 100%. This would make it possible to analyze the dependency of the priorities obtained in the equity variables.

AGRICULTURAL RESEARCH PRIORITIES IN COSTA RICA

Context

Perhaps the most interesting aspect of the Costa Rican agriculture sector is the fact that it has developed a dynamic and flexible capacity to respond to signals and opportunities as they arise on the international market. This has led it to constantly diversify its agricultural exports. According to FAO data, while in 1980 nontraditional products accounted for only 12% of the value of agricultural exports, by 1990 they accounted for 25%.

This is why it is advisable to ensure that a model for establishing agricultural research priorities at the macro level reflects, through the variables with which it operates, the comparative advantages and potential opportunities available to producers on the international market (Schuh and Norton 1991). However, it is also necessary to consider possible exchanges that occur with respect to equity and sustainability, and thus, it is important to include variables pertaining to food security and environmental conservation.

Structure of the NARS in Costa Rica (1992)

The Costa Rican NARS is made up of a widely varied range of public and private institutions that conduct agricultural research with independent mandates and budgets.

The public sector NARS conducting research on agricultural products is concentrated mainly in the University of Costa Rica (UCR) and the Ministry of Agriculture (MAG). These institutions generally carry out research on categories that are included in the food basket (associated with a low-demand income elasticity) or produced by a large number of small farmers (see appendix).

The main private sector institutions in the NARS tend to specialize in research (or subcontract it) and marketing in a single product. For example, the Instituto Costarricense del Café (Costa Rican Coffee Institute–ICAFE) specializes in coffee, the Dirección en Investigación en Caña de Azúcar (Directorate of Sugarcane Research–DIECA) concentrates on sugarcane, and the Corporación Bananera Nacional (National Banana Corporation–CORBANA) is mainly concerned with bananas. In addition, the Coalición de Iniciativas de Desarrollo (Costa Rican Investment and Trade Development Board–CINDE) promotes the development of nontraditional export commodities and funds research on some of them.

In contrast with a NARS such as the one in Panama, where a few institutions do research on a large number of categories (Cuéllar 1990), the Costa Rican NARS is more diversified, inasmuch as its institutions conduct research on a few products, and there is hardly any overlapping in the categories studied.

Given this situation, there are within the NARS linkages between the product studied and the institution involved. In Costa Rica, research on certain products is directed by specific institutions, and, thus, a ranking of products could implicitly establish a ranking of institutions.

Rationale for Establishing Research Priorities in Costa Rica

As a result of the macroeconomic adjustment, governmental expenditure in terms of GDP has tended to fall. By the same token, operating resources for research activities in the public sector have become increasingly scarce in relative terms.

Given the existing ties between categories and institutions, the public research institutions do not carry out research on every product. It is useful for them to establish an overall ranking of agricultural categories in order to have the ability to direct the allocation of public funds for agricultural research in accordance with objectives that are consistent with the National Development Plan set up by the government. This so as to place them in perspective within the plan and capitalize on current trends in the international economy.

Methodology

The 1990-1994 National Development Plan includes the following overall objectives for the new Costa Rican development model:

— To attain sustained growth . . . based . . . on greater opening up of the economy and a reduction of distortions in order to transform the production structure through a more effective and just process for distribution of income.

— To guarantee rational utilization of natural resources, along with the preservation and restoration of essential ecological processes. (MIDEPLAN 1991)

The list of products for which Costa Rica needs to establish priorities is shown in Table 2. Information on variables for the relevant categories was obtained from local secondary sources and from FAO, for 1989 and 1990.

In order to guide the identification of priorities and in accordance with the objectives of the plan, the objectives of efficiency, equity, and sustainability were chosen. The variables associated with those objectives are shown in Table 3.

Very little information was obtained from secondary sources; therefore, interviews were conducted with officials, especially MAG and UCR researchers, in order to supplement and verify certain quantitative variables. This was the case with the variables pertaining to growth of demand, comparative advantage, research experience, number of farmers, levels of self-consumption, and importance of the products selected in the average daily diet in terms of calories and proteins.

In order to determine the weighting factors for formula 1 in section 2, the three scenarios shown in Table 3 were considered. In scenario 1, the weights were obtained through interviews with MAG and UCR administrators and researchers. It is interesting to note that the weighting factor for the variable associated with sustainability is the highest (13%), since most of the people interviewed assigned a high weighting factor to that variable.

Scenario 2 was designed to analyze how to vary the priorities with respect to scenario 1, when the weights of the variables vary in favor of a research policy that stresses the equity objective, as greater importance is assigned to the variables associated with the distributive impact of research.

Table 2. Costa Rica: Products proposed for inclusion in priority-setting for agricultural research.

1	Corn	13	Broccoli	25	Watermelon	37	Pejibaye
2	Beans	14	Cabbage	26	Cantaloupe	38	Pepper
3	Rice	15	Tomatoes	27	Papaya	39	Tobacco
4	Sorghu m	16	Lettuce	28	Pineapple	40	Cacao
5	Soybeans	17	Onions	29	Avocado	41	Macadamia
6	Cotton	18	Asparagus	30	Oranges	42	Cassava
7	Coffee	19	Carrots	31	Soursop	43	Roots and tubers
8	Bananas	20	Cauliflower	32	Strawberries	44	Poultry
9	Sugarca ne	21	Cucumber	33	Blackberries	45	Beef cattle
10	Ornamental plants	22	Bell peppers	34	Mangoes	46	Dairy cattle
11	Flowers	23	Chayote	35	Plantains	47	Swine
12	Potatoes	24	Passion fruit	36	African palm	48	Forestry

Source: Prepared by the author.

Scenario 3 was considered in order to discern the change in priorities (also in scenario 1) when research policy is focused on the efficiency objective and when greater importance is assigned to the variables associated with the economic importance of the product.

Results

The results obtained for the scenarios described are presented in Tables 4 and 5. In order to interpret the results, the 48 products should be divided into 4 groups of 12 products each by order of priority, that is, very high, high, medium, and low.

Scenario 1

The high-priority group (from 1 to 12) includes traditional and nontraditional products; among the latter are oranges, cantaloupe, roots and tubers, plantains, and strawberries. This is an interesting finding compared with the situation in El Salvador where the high-priority group only includes staples and nontraditional export products.

By contrast with the exercise in El Salvador, where the staple grains (corn, beans, rice, and sorghum) are in the first four places, in Costa Rica these categories are in the low-priority groups. This is partly due to the fact that in scenario 1, the weights assigned to the equity variables (29% overall) are relatively small in comparison with those assigned to the variables identified with the efficiency objective (61%).

Scenario 2

As might be expected, when the weighting factors in scenario 1 are changed to favor the variables associated with equity, the high-priority group includes important products in the food basket (low-demand elasticity with respect to income) or those that are produced by a large number of farmers, such as beans. By contrast, the low-priority group (from 37 to 48) mostly includes Nates associated with high income-elasticity with respect to demand (asparagus, macadamia, pepper, ornamental plants, and flowers) and products not included in the food basket and which are produced by a small number of farmers (cotton, soybeans, sorghum, and tobacco).

Scenario 3

When the weighting factors are changed to emphasize the economic efficiency objective in terms of the importance of the product, all the traditional export products appear in the highest priority group (from 1 to 120); nevertheless, this group is made up mainly of NTE products (oranges, chayote, cassava, papaya, and plantains), and includes three of the major NTE products: pineapple, cantaloupe, and roots and tubers.

With regard to scenario 1, corn and rice are ranked lower in priority and beans are given higher priority, while sorghum remains in last place.

In the three scenarios, plantains and roots and tubers are in the highest priority group. This finding is probably due, *inter alia,* to the following: (a) they are important in the Costa Rican diet; (b) they are gaining ground among nontraditional exports; and (c) according to the persons interviewed, the technologies used in producing roots and tubers are not harmful to the environment.

AGRICULTURAL RESEARCH PRIORITIES IN EL SALVADOR

Context

Agricultural research priorities in El Salvador were identified during 1990, when an alternative model for the generation and transfer of agricultural technology (AID-MAG-IICA 1990) was proposed. The general objectives of this model were to help increase per capita income in the country, improve food security, and promote the savings and generation of foreign exchange.

When there is a national agricultural research plan (whether operational or strategic), the public-sector priorities of the NARS will be included within the objectives of the plan. In practice, however, the relationship between the plan and the ARPs is a repetitive process: priorities are identified, the plan is drawn up, priorities are reformulated based on the plan.

Table 3. Quantitative and qualitative variables and scenarios considered in establishing priorities for categories of agricultural products.

Variables	Scenario 1	Scenario 2	Scenario 3
	Weighting factors obtained from interviews (weighting factors)	Emphasis on equity: associated weighting factors total 71% (weighting factors)	Emphasis on efficiency: associated weighting factors total 77% (weighting factors)*
Quantitative	%	%	%
1. Value of production	10	3	17[2]
2. Value of international trade	7	3	20[2]
3. Anticipated change in demand	4	3	20[2]
4. Comparative advantage (DCR)	7	3	20[2]
5. Research experience	5	3	2
6. Number of farmers	7	17[1]	2
7. Level of self-consumption	4	17[1]	2
8. Calories provided in average daily diet	4	17[1]	2
9. Proteins provided in average daily diet	3	17[1]	2
Qualitative			
10. Seriousness of problems to be solved through research	7	3	2
11. Private sector incentives	7	3	2
12. Technologies not harmful to environment	13	3	2
13. Impact on employment	8	3[1]	2
14. Information flows to and from international centers	3	3	2
15. Research potential (anticipated increase in yields)	10	3	2

* Figures are rounded; hence, the sum of weighting factors is not 100%.

1. Variables associated with the "equity" objective.
2. Variables associated with the economic importance of the product.

Source: Prepared by the author.

Table 4. Costa Rica: Research priorities under scenarios 1 and 2.

Scenario 1			Scenario 2 (emphasis on equity)		
Priority	Product	Score	Priority	Product	Score
1.	Bananas	38.64	1.	Beans	40.92
2.	Oranges	37.81	2.	Cassava	38.83
3.	Cantaloupe	37.75	3.	Roots and tubers	38.58
4.	Plantains	37.21	4.	Potatoes	38.46
5.	Cattle (beef)	36.90	5.	Corn	38.43
6.	Cattle (dairy)	36.59	6.	Plantains	37.10
7.	Coffee	36.39	7.	Papaya	36.05
8.	Sugarcane	35.88	8.	Cattle (dairy)	35.94
9.	Potatoes	35.76	9.	Poultry	35.82
10.	Roots and tubers	35.49	10.	Tomatoes	35.81
11.	Poultry	35.00	11.	Rice	35.18
12.	Strawberries	34.95	12.	Cabbage	34.53
13.	Mangoes	34.90	13.	Strawberries	34.34
14.	Pineapple	34.54	14.	Chayote	33.98
15.	Cassava	34.50	15.	Bell peppers	33.88
16.	Tomatoes	34.33	16.	Carrots	33.70
17.	Cacao	33.73	17.	Sugarcane	33.43
18.	Papaya	33.17	18.	Oranges	32.70
19.	Swine	33.07	19.	Bananas	32.69
20.	Chayote	33.07	20.	Swine	32.66
21.	Corn	32.43	21.	Cattle (beef)	32.56
22.	Soursop	32.42	22.	Mangoes	31.33
23.	Passion fruit	32.42	23.	Cantaloupe	31.15
24.	Blackberries	32.35	24.	Blackberries	31.09
25.	Beans	31.68	25.	Onions	30.71
26.	Bell peppers	31.13	26.	Coffee	30.41
27.	Macadamia	30.98	27.	Lettuce	30.40
28.	Onions	30.59	28.	Avocado	30.32
29.	Avocado	30.40	29.	Cauliflower	29.51
30.	Cabbage	30.11	30.	Soursop	29.13
31.	Rice	29.24	31.	Pejibaye	28.36
32.	Lumber	29.22	32.	Cucumbers	28.35
33.	Pejibaye	29.04	33.	Pineapple	27.79
34.	Carrots	28.84	34.	Broccoli	27.59
35.	Lettuce	28.36	35.	Cacao	27.37
36.	Broccoli	28.31	36.	Passion fruit	26.83
37.	African palm	28.27	37.	African palm	25.32
38.	Asparagus	27.58	38.	Watermelon	24.22
39.	Cauliflower	27.09	39.	Asparagus	23.18
40.	Watermelon	26.45	40.	Macadamia	21.69
41.	Ornamental plants	26.34	41.	Pepper	20.34
42.	Tobacco	26.34	42.	Lumber	17.89
43.	Cucumber	25.95	43.	Soybeans	16.00
44.	Flowers	25.65	44.	Tobacco	15.57
45.	Pepper	23.56	45.	Cotton	15.53
46.	Cotton	18.95	46.	Sorghum	15.41
47.	Soybean	18.44	47.	Ornamental plants	14.55
48.	Sorghum	16.55	48.	Flowers	14.31

Source: Prepared by the author.

Table 5. Costa Rica: Research priorities under scenarios 1 and 3.

Scenario 1			Scenario 3 (emphasis on economic significance of product)		
Priority	**Product**	**Score**	**Priority**	**Product**	**Score**
1.	Bananas	38.64	1.	Bananas	44.45
2.	Oranges	37.81	2.	Coffee	41.88
3.	Cantaloupe	37.75	3.	Pineapple	38.66
4.	Plantains	37.21	4.	Sugarcane	38.43
5.	Cattle (beef)	36.90	5.	Cantaloupe	37.60
6.	Cattle (dairy)	36.59	6.	Roots and tubers	36.11
7.	Coffee	36.39	7.	Oranges	35.71
8.	Sugarcane	35.88	8.	Chayote	34.59
9.	Potatoes	35.76	9.	Cattle (beef)	34.50
10.	Roots and tubers	35.49	10.	Cassava	32.57
11.	Poultry	35.00	11.	Papaya	31.73
12.	Strawberries	34.95	12.	Plantains	31.72
13.	Mangoes	34.90	13.	Cattle (dairy)	31.09
14.	Pineapple	34.54	14.	Tomatoes	31.07
15.	Cassava	34.50	15.	Pejibaye	30.78
16.	Tomatoes	34.33	16.	Strawberries	30.50
17.	Cacao	33.73	17.	Macadamia	30.48
18.	Papaya	33.17	18.	Mangoes	30.43
19.	Swine	33.07	19.	Ornamental plants	29.71
20.	Chayote	33.07	20.	Poultry	28.41
21.	Corn	32.43	21.	Beans	27.85
22.	Soursop	32.42	22.	Blackberries	27.73
23.	Passion fruit	32.42	23.	Corn	27.64
24.	Blackberries	32.35	24.	Flowers	27.61
25.	Beans	31.68	25.	Asparagus	27.18
26.	Bell peppers	31.13	26.	Passion fruit	26.94
27.	Macadamia	30.98	27.	Bell peppers	26.87
28.	Onions	30.59	28.	Onions	25.80
29.	Avocado	30.40	29.	African palm	25.67
30.	Cabbage	30.11	30.	Carrots	24.42
31.	Rice	29.24	31.	Potatoes	24.30
32.	Lumber	29.22	32.	Soursop	24.23
33.	Pejibaye	29.04	33.	Avocado	23.74
34.	Carrots	28.84	34.	Swine	23.72
35.	Lettuce	28.36	35.	Watermelon	23.62
36.	Broccoli	28.31	36.	Lumber	23.00
37.	African palm	28.27	37.	Rice	22.59
38.	Asparagus	27.58	38.	Cabbage	22.52
39.	Cauliflower	27.09	39.	Cacao	22.31
40.	Watermelon	26.45	40.	Lettuce	18.30
41.	Ornamental plants	26.34	41.	Cucumber	18.27
42.	Tobacco	26.34	42.	Pepper	18.03
43.	Cucumber	25.95	43.	Broccoli	17.88
44.	Flowers	25.65	44.	Tobacco	17.74
45.	Pepper	23.56	45.	Cauliflower	17.52
46.	Cotton	18.95	46.	Cotton	14.97
47.	Soybeans	18.44	47.	Soybean	14.04
48.	Sorghum	16.15	48.	Sorghum	9.22

Source: Prepared by the author.

In this process, information is exchanged at all levels of the hierarchy, both top down and bottom up (Contant and Bottomley 1988). In El Salvador, the first step in the process consisted of drawing up a proposed alternative model for generating and transferring technology.

In addition, in order to place research priorities in the perspective of the public-sector NARS, it is important to describe the public entities that were part of the national research and technology transfer system (NRTTS) of El Salvador in October 1990, when the priority-setting exercise was carried out. At that time, there was a proposal for restructuring the entities of the system and bringing them together into a single decentralized institution under the Ministry of Agriculture: the Centro Nacional de Tecnología Agrícola (National Center for Agricultural Technology–CENTA), the Centro de Desarrollo Ganadero (Livestock Development Center–CDG), four regional management offices of the Ministry of Agriculture (MAG) and the Centro Nacional de Capacitación Agropecuaria (National Agricultural Training Center–CENCAP). In 1990, CENTA carried out research activities on the crops listed in the appendix.

Methodology

Bearing in mind the alternative model for generating and transferring agricultural technology proposed to orient priority setting in El Salvador, the objectives of efficiency and equity were chosen. The variables associated with these objectives are shown in Table 6.

The CENTA technical staff proposed the list of products to be included in the priorities for El Salvador; this list is shown in Table 6. The information on variables pertaining to the categories of products was obtained from local secondary sources and from FAO, for 1988 and 1989, from interviews with CENTA and CDG researchers and administrators.

Table 6. El Salvador: Products proposed for inclusion in priority-setting for agricultural research.

1	Corn	11	Bell peppers	21	Cantaloupe	31	Hemp
2	Beans	12	Cucumbers	22	Watermelon	32	Eggs
3	Rice	13	Plantains	23	Mangoes	33	Poultry
4	Sorghum	14	Bananas	24	Cashew	34	Cattle (beef)
5	Cabbage	15	Avocado	25	Coffee	35	Swine
6	Tomatoes	16	Coconut	26	Sugarcane	36	Cattle (dairy)
7	Potatoes	17	Pineapple	27	Cotton	37	Honey
8	Onions	18	Lemons	28	Sesame	38	Lumber
9	Lettuce	19	Oranges	29	Soybeans		
10	Carrots	20	Papaya	30	Peanuts		

Source: Prepared by the author.

The data for determining weighting factors for each variable were obtained from interviews with CENTA administrators and researchers. The weighting factors, which were calculated as described above, are shown in Table 7. It should be noted that the people interviewed, mostly CENTA researchers, attached the greatest importance to the variables pertaining to research potential (seriousness of problems and increase in anticipated yield), which together represent a weight of 22%. The variables associated with the importance of the product totaled 25%, while those associated with equity totalled 28%.

Table 7. Quantitative and qualitative variables and weighting factors.

Variables	Weighting factors*
Quantitative	%
1. Value of production	10
2. Value of international trade	5
3. Anticipated change in demand	5
4. Comparative advantage (DCR)	5
5. Research experience	6
6. Number of farmers	5
7. Level of self-consumption	5
8. Calories provided in average daily diet	4
9. Proteins provided in average daily diet	5
Qualitative	
10. Seriousness of problems to be solved through research	11
11. Private-sector incentives	6
12. Current research emphasis	8
13. Use of and savings in resources	9
14. Information flows to and from international centers	5
15. Research potential (anticipated increase in yields)	11

* As rounded figures are used, the total will not necessarily be 100%.

Results

As shown in Table 8, staple grains (corn, beans, rice, and sorghum) are ranked in the first four places, and export commodities (coffee and sugarcane) and beef and dairy cattle are in the highest priority group.

In general terms, the priority established for the 38 products supports the proposal put forth by AID-MAG-IICA (1990:12, 13), which stated that priority should be given to staple grains and dual-purpose cattle growing, as well as to specialized milk production; vegetables and fruits represent the second level of priority.

Evidently, some of the priorities established will depend on the weighting factors that are obtained. Thus, scores for staple grains were always quite high with almost every variable, and are expected to remain in the first priority group, independently of whatever the weighting factors might be.

Table 8. El Salvador: Research priorities.

Priority	Product	Score
1.	Corn	35.50
2.	Beans	34.41
3.	Rice	33.30
4.	Sorghum	32.35
5.	Coffee	30.75
6.	Sugarcane	29.09
7.	Milk	28.82
8.	Cattle (beef)	28.38
9.	Tomatoes	28.24
10.	Bananas	27.94
11.	Papaya	27.41
12.	Poultry	27.33
13.	Swine	27.17
14.	Plantains	27.11
15.	Lumber	27.02
16.	Honey	26.52
17.	Potatoes	26.17
18.	Eggs	26.04
19.	Coconut	25.75
20.	Pineapple	25.05
21.	Oranges	24.92
22.	Lemon	24.39
23.	Avocado	24.05
24.	Cantaloupe	23.87
25.	Cabbage	23.85
26.	Onions	23.57
27.	Watermelon	23.15
28.	Carrots	22.81
29.	Sesame	22.81
30.	Peppers	22.42
31.	Soybeans	22.42
32.	Cucumbers	22.14
33.	Mangoes	20.09
34.	Peanuts	20.00
35.	Cotton	19.83
36.	Lettuce	19.31
37.	Cashew	14.24
38.	Hemp	07.56

Source: Prepared by the author.

AGRICULTURAL RESEARCH PRIORITIES IN GUATEMALA

Context

In Guatemala, ARPs were identified during 1991, when the sphere of action of the public-sector NRTTS with respect to the private sector was being redefined and special attention was being given to determining which categories of production and which disciplines should be researched.

In Guatemala, the main public institution of the NARS is the Instituto de Ciencias y Tecnología Agrícolas (Institute of Agricultural Science and Technology–ICTA), a unit of the Ministry of Agriculture, Livestock, and Food (MAGA). This ministry has two agricultural extension services: the Dirección General de Servicios Agrícolas (General Directorate of Agricultural Services–DIGESA) and the Dirección General de Servicios Pecuarios (General Directorate of Livestock Services–DIGESEPE).

In addition, the Gremial de Exportadores de Productos No Tradicionales (Association of Exporters of Nontraditional Products–GEXPRONT) is a significant promoter of the private-sector NARS, which channels offers of technical assistance such as those of the Proyecto de Apoyo Tecnológico para las Industrias de Exportación (Project on Technological Support for Export Industries–PROEXAG) and other agencies. PROEXAG is a Central American project based in Guatemala that provides technical assistance in connection with production, postharvest, marketing, and transport, and also supports research on the adaptation of technologies (Kaimowitz 1992).

In that context, it was pertinent for ICTA to be able to establish research priorities by product categories, inasmuch as this would provide useful information in determining which categories should be emphasized or maintained in research programs, in order to achieve previously established objectives. This information was very useful at a time when public-sector activities of the NARS were undergoing revision and adjustment.

Methodology

The MAGA document on agricultural policy sets forth the following general objective:

To structure the bases for economic reactivation and sustained development of agricultural production . . . in an atmosphere of peace and tranquility, supporting entrepreneurial management processes, technology generation and transfer, funding for the agriculture sector[,] . . . modernizing public management and development production systems that are compatible with conservation . . . of natural resources." (MAGA 1991)

The list of products to be ranked for priority, proposed by ICTA technicians, is shown in Table 8. The information on quantitative variables was obtained, for 1989 and 1990, from local secondary sources and FAO yearbooks. In general, very little information was available from secondary sources. Information on some variables was verified through interviews with officials of ICTA, the IICA office in Guatemala and the Nutrition Institute of Central America and Panama (INCAP).

The weighting factors for the variables considered are shown in Table 9. These were determined by averaging the weighting factors assigned by ICTA researchers and administrators.

Table 9. Guatemala: Products proposed as priorities for agricultural research.

1 Corn	12 Tomatoes	23 Papaya	34 Plantains
2 Beans	13 Lettuce	24 Apples	35 Tobacco
3 Rice	14 Onions	25 Pears	36 Cacao
4 Sorghum	15 Asparagus	26 Peaches	37 Coffee
5 Wheat	16 Carrots	27 Cashew	38 Sugar cane
6 Sesame	17 Cauliflower	28 Grapes	39 Cotton
7 Soybeans	18 Cucumbers	29 Citrusfruits	40 Lemon tea
8 Okra	19 Sweet potatoes	30 Mangoes	41 Citronella
9 Potatoes	20 Bell peppers	31 Peanuts	42 Dual-purpose cattle
10 Broccoli	21 Wate rmelon	32 Cardamom	
11 Cabbage	22 Cant aloupe	33 Bananas	43 Forestry products

Source: Prepared by the author.

Results

The ARPs were identified according to the procedure described in chapter 2. These are shown in Table 10, in the first column under the heading "Current priority."

The top ten priorities were assigned to traditional export commodities (coffee, bananas, and sugarcane) and products that constitute staple foods for the Guatemalan population, such as basic grains.

In setting agricultural research priorities for Guatemala, the objectives of economic efficiency and equity were considered. The variables associated with those objectives are described in Table 9.

In Table 10, the figures in the third column, under the heading "Implicit priority," indicate the importance attached to each product in terms of resources assigned to research. Implicit priority was estimated by using as a proxy variable the number of researcher-years devoted to it over the past five years. This variable may also be taken as a proxy for the supply of technology in the corresponding product. The last column in Table 10

Table 10. Weighting factors and quantitative and qualitative variables.

Variables	Weighting factors*
Quantitative	%
1. Value of production	10
2. Value of international trade	8
3. Anticipated change in demand	4
4. Comparative advantage (DCR)	7
5. Research experience	3
6. Number of farmers	8
7. Level of self-consumption	3
8. Calories provided in average daily diet	3
9. Proteins provided in average daily diet	3
Qualitative	
10. Seriousness of problems to be solved through research	12
11. Private-sector incentives	6
12. Current research emphasis	7
13. Use of and savings in resources (manpower)	9
14. Information flows to and from international centers	6
15. Research potential (anticipated increase in yields)	11

* The sum of weighting factors is not 100%, as rounded figures are used.

Source: Prepared by the author.

shows the categories for which the current priority is higher than the implicit priority. The priorities identified in the first column show a bias toward demand for technology, and most of the variables that determine them remained fixed over the short term (Fig. 1). Implicit priorities, on the other hand, represent the supply of technology. The last column shows those categories for which there is an excess of demand for technology, and on which research efforts should be increased.

By dividing the categories in Table 10 into groups of 11 products, four groups are obtained: those to which very high priority is assigned (1-11), which are traditional export commodities and staple food products; those having high priority (12-22), basically vegetables; those with medium priority 23-33); and those with very low priority (34-43).

Evidently, the priority ranking shown in Table 10 is mostly based on the values of the weighting factors obtained from surveys. In this case, the respondents stressed the variables pertaining to economic efficiency, 74% all together (the weighting factors of the variables relating to the importance of the product totaled 29%), more than the variables pertaining to equity, which totaled 26%.

Table 11. Guatemala: Agricultural research priorities by product.

Current priority	Product	Implicit priority*	Score	Categories whose priority increases with respect to implicit priority
1.	Coffee	1.	37.97	
2.	Bananas	14.	37.06	+
3.	Tomatoes	15.	36.74	+
4.	Potatoes	7.	36.29	+
5.	Sugarcane	22.	36.20	+
6.	Dual-purpose livestock	5.	35.96	
7.	Wheat	4.	35.56	
8.	Corn	3.	35.43	
9.	Beans	1.	34.53	
10.	Cardamom	33.	34.44	+
11.	Cotton	10.	33.97	
12.	Carrots	27.	33.87	+
13.	Cabbage	18.	33.77	+
14.	Broccoli	18.	33.70	+
15.	Cauliflower	27.	33.44	+
16.	Rice	8.	33.16	
17.	Bell peppers	41.	32.94	+
18.	Onions	18.	32.93	
19.	Cucumbers	27.	32.80	+
20.	Asparagus	42.	32.26	+
21.	Forestry products	33.	32.18	+
22.	Plantains	33.	32.02	+
23.	Citrus fruits	16.	31.95	
24.	Tobacco	6.	31.83	
25.	Sweet potatoes	42.	31.71	+
26.	Apples	10.	31.61	
27.	Lettuce	18.	31.39	
28.	Peaches	16.	30.63	
29.	Cantaloupe	27.	29.84	
30.	Pears	10.	29.71	
31.	Sorghum	9.	29.56	
32.	Cacao	10.	26.90	
33.	Citronella	33.	26.49	
34.	Watermelon	40.	26.43	+
35.	Mangoes	32.	26.30	
36.	Lemon tea	22.	26.05	
37.	Papaya	33.	26.02	
38.	Okra	27.	25.30	
39.	Cashew	33.	24.88	
40.	Peanuts	33.	24.60	
41.	Sesame	22.	22.44	
42.	Grapes	22.	22.29	
43.	Soybeans	22.	19.77	

* Implicit priority indicates the order in terms of researcher-years assigned to each product over the past five years.

Source: Prepared by the author.

It is expected that if the weighting factors of the variables pertaining to equity are increased, but those pertaining to the other variables are reduced in order to keep the sum of all weighting factors equal to 100%, the priorities of staple grains (particularly corn, beans, and wheat) would increase, inasmuch as they are ranked at the top of the list of variables pertaining to equity.

AGRICULTURAL RESEARCH PRIORITIES IN HONDURAS

Context

In Honduras, the ARPs were identified during 1992, at a time when the spheres of action of the public and private sectors were being redefined.

Structure of the Honduran NARS (1992)

The Honduran NARS covers all the national institutions that generate agricultural technology. In the public-sector NARS, the following institutions generate final-product technology: the Dirección de Investigación Agrícola (Directorate of Agricultural Research–DIA), the Dirección de Investigación Pecuaria (Directorate of Livestock Research–DIP) and the Centro Universitario Regional del Litoral Atlántico (Regional University Center of the Atlantic Coast–CURLA). These institutions focus their efforts on staple grains, vegetables, oilseeds, and certain animal products. The main clients for these public institutions are small- and medium-scale farmers (SRN 1991).

The main private agricultural research institutions are the Fundación Hondureña de Investigación Agrícola (Honduran Agricultural Research Foundation), the Escuela Agrícola Panamericana El Zamorano (El Zamorano Pan American School of Agriculture–EAP), the banana growers, sugar mills, tobacco manufacturing companies, and the Instituto Hondureño del Café (Honduran Coffee Institute–IHCAFE).

The Honduran Agricultural Research Foundation (FHIA) focuses its work on traditional export (e.g., bananas) and nontraditional (e.g., plantains) commodities. Its main clients are large-scale producers of export crops. The El Zamorano school conducts research as a supplement to its educational program in the area of livestock, seed production, vegetables, sorghum, and beans. The banana, sugar, and tobacco companies are conducting research on their specific products. The research findings are applied by these companies and by the producers who have production contracts with them. Finally, IHCAFE conducts studies mostly on coffee and other diversification crops, such as cacao, macadamia, cardamom, and pepper. Its main clients are the coffee producers (SRN 1991).

As in the case of Costa Rica, within the NARS the sector that generates final-product technology is diversified and monopolistic, in the sense that many institutions are conducting research on different crops, in different categories, almost none of which is being studied by more than two institutions. In this regard, there is a linkage between the product and the institutions.

In addition, whereas the public institutions, such as the Secretariat of Natural Resources (SRN), are conducting research on products associated with the basic diet (usually those having a low-demand elasticity with respect to income), which produces innovations which, when adopted, tend to benefit consumers more than producers, the opposite is true with the private institutions (such as FHIA), since they are researching exports products that usually have a relatively high income elasticity of demand, and its innovations, when adopted, benefit producers more than consumers (Medina Castro 1991a).

Reasons for Setting Priorities in Honduras

Given the fact that in 1992 Honduran institutions concerned with the generation of technology were closely linked with specific categories of products, an exercise in setting priorities for agricultural research by product would also implicitly involve setting priorities for research institutions, at least for the short term, until the institutions changed their own research focus.

Bearing in mind certain specific objectives and the relative emphasis placed on each one, the exercise would also indicate the ARPs of the NARS as a whole. This in turn would provide useful information for analyzing the rationale behind the allocation of resources between and within institutions in order to attain the objectives.

This is very useful during a stage of restructuring of the state apparatus, when (a) decisions are being made as to which of the agricultural research activities being carried out by the public sector in Honduras should be continued and which should be absorbed by the private sector; and (b) a public agency is being created which, in agreement with private entities and producers, would coordinate technology generation and transfer activities for the Honduran NARS.

At the present time (1992), in fact, the SRN has created the Dirección de Ciencia y Tecnología Agropecuaria (Directorate of Agricultural Science and Technology–DICTA), one of the purposes of which is to "rationalize technology generation and transfer services" in cooperation with the private sector (*Ley para la Modernización y el Desarrollo del Sector Agropecuario* 1992:art.36). The SRN is also responsible for establishing priorities for agricultural technology generation and transfer services in coordination with other public institutions and producers (*Ley para la Modernización y el Desarrollo del Sector Agropecuario* 1992:art.38).

Thus, if there is a flexible methodology covering several objectives that are all aimed at improving the well-being of society as a whole, the importance of certain agricultural products within the overall framework of the NARS could be envisaged.

For example, if emphasis were placed on objectives that were closely related with food security, it is likely that in establishing the ARPs by agricultural product, research on staple foods would be important and, consequently, in terms of technology generation, so would the entities that carry out research on those foods. If the emphasis were on generating foreign exchange, export products would probably be significant and so would agricultural research along those lines.

Methodology

The list of products included in the priority-setting exercise is shown in Table 12. The information on quantitative variables was valid for 1990 and 1991. In general, there was not enough information from secondary sources, and for some products, the data on value of production, international trade, and number of farmers had to be supplemented or estimated. The DCR coefficient, used in connection with comparative advantage, was estimated with the help of economists from the IICA office in Honduras.

Table 12. Honduras: Products proposed as priorities for agricultural research.

1. Corn	13. Onions	25. Peanuts	37. Plantains
2. Beans	14. Tomatoes	26. Passion fruit	38. Cashew
3. Rice	15. Pumpkin	27. Tamarind	39. Coconut
4. Sorghum	16. Cabbage	28. Citrus fruits	40. Mangoes
5. Soy beans	17. Carrots	29. Grapes	41. Poultry
6. Sesame	18. Chile	30. Avocado	42. Swine
7. Cotton	19. Cucumber	31. Apples	43. Dual-purpose cattle
8. Coffee	20. Lettuce	32. Pineapple	
9. Cacao	21. Potatoes	33. Peaches	44. Goats
10. Bananas	22. Beets	34. Papaya	45. Forestry products
11. Sugarcane	23. Cassava	35. Cantalou pe	
12. African palm	24. Garlic	36. Watermelon	

Source: Prepared by the author.

Bearing in mind an economic development pattern that allows for production to be increased in a context of social justice and preserving the natural resource base, agricultural research priorities were identified bearing in mind the following three objectives: efficiency, equity, and sustainability. The variables associated with those objectives in Honduras are shown in Table 12.

As in the cases of Costa Rica and Panama, three scenarios were considered in determining the weighting factors described in formula 1. These scenarios are also shown in Table 13.

The weighting factors for the first scenario were determined through interviews with researchers and administrators concerned with agricultural research. The values for scenarios 2 and 3 were determined "arbitrarily." In scenario 2, greater significance was attached to variables pertaining to equity, in order to determine how they change priorities when research policy stresses the equity objective through the impact in terms of distribution. In scenario 3, greater emphasis was placed on economic efficiency, especially those factors pertaining to the importance of the product.

Table 13. Quantitative and qualitative variables considered in setting priorities for categories of agricultural production in Honduras.

Variables	Scenario 1	Scenario 2	Scenario 3
	Weighting factors obtained from interviews (weighting factors)	Emphasis on equity: associated weighting factors total 67% (weighting factors)	Emphasis on efficiency: associated weighting factors total 67% (weighting factors)*
Quantitative	%	%	%
1. Value of production	6	3	17[2]
2. Value of international trade	4	3	17[2]
3. Anticipated change in demand	8	3	17[2]
4. Comparative advantage (DCR)	3	3	17[2]
5. Research experience	7	3	3
6. Number of farmers	11	17[1]	3
7. Level of self-consumption	6	17[1]	3
8. Calories provided in average daily diet	2	17[1]	3
9. Proteins provided in average daily diet	1	17[1]	3
Qualitative			
10. Seriousness of problems to be solved through research	12	3	3
11. Private sector incentives	4	3	3
12. Technologies not harmful to environment	9	3	3
13. Impact on employment	6	3[1]	3
14. Information flows to and from international centers	6	3	3
15. Research potential (anticipated increase in yields)	15	3	3

* The sum of weighting factors is not 100% because rounded figures are used.

1. Variables associated with the equity objective.
2. Variables associated with economic importance of the product.

Source: Prepared by the author.

Results

The results obtained are shown in Tables 14 and 15. The following analysis is not exhaustive. The 45 products were divided into four groups, one comprising 12 products and three comprising 11 products each, in the following order of priority: very high, high, medium, and low.

Scenario 1

The "very high" priority group (1-12) includes traditional export commodities (bananas, coffee, and beef cattle) and products that are important in the diet of the population of Honduras (corn, beans, rice, dairy and beef cattle, plantains, and potatoes). The lowest priority group is made up mainly of fruits and some vegetables.

In comparing this exercise with the one on Costa Rica, it is interesting to note that in this scenario, soybeans are included in the highest priority group (partly because during the 1990-91 period, soybean imports were among the largest in volume and the demand is expect to increase considerably in future). In Costa Rica, in any scenario, soybeans are in the lowest priority group.

Scenario 2

When the weighting factors for scenario 1 are biased toward variables associated with equity, almost all the products that play a significant role in the basic food basket are included in the highest priority group. Indeed, this group includes the main staple grains (corn, beans, and rice), meat (beef, poultry, and pork), eggs (poultry), flours (banana, plantain, potato, and cassava) and cow milk.

Scenario 3

When the weighting factors are changed to emphasize the economic efficiency objective in terms of the importance of the product (except for forestry products), traditional export commodities (bananas, coffee, beef, and sugarcane) are included in the highest priority group. This group also includes the main nontraditional export commodities such as pineapple, cantaloupe, cacao, citrus fruits, and plantains. Soybeans are included because of their significance as an import product during 1990 and 1991.

A comparison of the results of scenarios 2 and 3 with respect to staple grains shows that in scenario 3, they move into the second priority group (13-23). Basically, this is due to the fact that these products do not have significant comparative advantages and they are not important in international trade (i.e., during 1990-91).

In all three scenarios, the highest priority groups include bananas, cattle, plantains, and potatoes. Among other things, this can be explained by the following: (a) they are important in the diet of the Honduran population, (b) they are important exports, or (c), as in the case of potatoes, they are significant because of the number of farmers producing them and because of the level of self-consumption.

Table 14. Honduras: Research priorities under scenarios 1 and 2.

Scenario 1			Scenario 2 (emphasis on equity)		
Priority	**Product**	**Score**	**Priority**	**Product**	**Score**
1.	Bananas	40.59	1.	Corn	41.25
2.	Coffee	40.56	2.	Beans	40.45
3.	Corn	40.28	3.	Cattle (dual purpose)	40.01
4.	Cattle (dual purpose)	40.00	4.	Rice	38.95
5.	Plantains	39.82	5.	Potatoes	38.31
6.	Potatoes	39.61	6.	Plantains	37.93
7.	Beans	39.34	7.	Bananas	36.00
8.	Tomatoes	38.26	8.	Swine	34.80
9.	Rice	38.16	9.	Poultry	34.79
10.	Mangoes	37.63	10.	Citrus fruits	34.16
11.	Soybeans	37.17	11.	Pineapple	33.97
12.	Cacao	36.90	12.	Cassava	33.51
13.	Citrus fruits	36.83	13.	Mangoes	32.95
14.	Poultry	35.92	14.	Watermelon	32.73
15.	Cantaloupe	35.76	15.	Coffee	32.14
16.	Watermelon	35.61	16.	Tomatoes	31.44
17.	Pineapple	35.33	17.	Cantaloupe	30.91
18.	Sorghum	34.12	18.	Avocado	29.31
19.	Cabbage	33.97	19.	Cabbage	28.94
20.	Swine	33.30	20.	Sorghum	28.52
21.	Garlic	32.95	21.	Cacao	28.12
22.	Goats	32.94	22.	Tamarind	27.70
23.	Avocado	32.36	23.	Cashew	27.55
24.	Cassava	31.78	24.	Onions	27.52
25.	Sugarcane	31.68	25.	Sugarcane	27.49
26.	Forestry products	31.42	26.	Soybeans	27.39
27.	Grapes	31.03	27.	Carrots	26.51
28.	Onions	30.89	28.	African palm	26.13
29.	Pumpkin	30.80	29.	Pumpkin	25.18
30.	Sesame	30.28	30.	Coconut	25.06
31.	Chile	30.16	31.	Papaya	25.06
32.	Coconut	29.87	32.	Cucumber	24.41
33.	Cucumbers	29.86	33.	Goats	24.28
34.	African palm	29.70	34.	Chile	23.56
35.	Apples	29.38	35.	Beets	22.58
36.	Cashew	29.12	36.	Sesame	22.42
37.	Tamarind	28.30	37.	Lettuce	21.94
38.	Cotton	27.19	38.	Garlic	21.45
39.	Carrots	27.08	39.	Peaches	21.16
40.	Peaches	26.76	40.	Grapes	20.52
41.	Beets	26.29	41.	Apples	19.68
42.	Lettuce	25.60	42.	Forestry products	19.55
43.	Papaya	25.07	43.	Peanuts	17.94
44.	Peanuts	24.24	44.	Passion fruit	17.61
45.	Passion fruit	23.77	45.	Cotton	14.93

Source: Prepared by the author.

Table 15. Honduras: Research priorities under scenarios 1 and 3.

Scenarios 1			Scenarios 3 (emphasis on economic importance of product)		
Priority	**Product**	**Score**	**Priority**	**Product**	**Score**
1.	Bananas	40.59	1.	Bananas	42.74
2.	Coffee	40.56	2.	Cattle (dual-purpose)	39.46
3.	Corn	40.28	3.	Plantains	37.66
4.	Cattle (dual-purpose)	40.00	4.	Coffee	36.95
5.	Plantains	39.82	5.	Cacao	35.82
6.	Potatoes	39.61	6.	Pineapple	35.48
7.	Beans	39.34	7.	Poultry	35.48
8.	Tomatoes	38.26	8.	Citrus fruits	34.98
9.	Rice	38.16	9.	Cantaloupe	34.21
10.	Mangoes	37.63	10.	Soybeans	33.30
11.	Soybeans	37.17	11.	Potatoes	32.67
12.	Cacao	36.90	12.	Sugarcane	32.58
13.	Citrus fruits	36.83	13.	Watermelon	31.90
14.	Poultry	35.92	14.	Mangoes	31.71
15.	Cantaloupe	35.76	15.	Tomatoes	31.44
16.	Watermelon	35.61	16.	Forestry products	29.59
17.	Pineapple	35.33	17.	Corn	29.15
18.	Sorghum	34.12	18.	Pumpkin	28.89
19.	Cabbage	33.97	19.	Onions	28.62
20.	Swine	33.30	20.	Beans	28.49
21.	Garlic	32.95	21.	Rice	26.99
22.	Goats	32.94	22.	Coconut	26.99
23.	Avocado	32.36	23.	Garlic	26.95
24.	Cassava	31.78	24.	Cucumber	25.65
25.	Sugarcane	31.68	25.	African palm	25.58
26.	Forestry products	31.42	26.	Cabbage	25.23
27.	Grapes	31.03	27.	Cassava	25.12
28.	Onions	30.89	28.	Sesame	24.89
29.	Pumpkin	30.80	29.	Swine	24.62
30.	Sesame	30.28	30.	Goats	24.55
31.	Chile	30.16	31.	Avocado	24.22
32.	Coconut	29.87	32.	Cashew	23.97
33.	Cucumber	29.86	33.	Tamarind	23.30
34.	African palm	29.70	34.	Sorghum	23.16
35.	Apples	29.38	35.	Grapes	23.13
36.	Cashew	29.12	36.	Chile	22.60
37.	Tamarind	28.30	37.	Apples	21.61
38.	Cotton	27.19	38.	Peaches	20.88
39.	Carrots	27.08	39.	Carrots	20.74
40.	Peaches	26.76	40.	Lettuce	18.91
41.	Beets	26.29	41.	Beets	18.87
42.	Lettuce	25.60	42.	Peanuts	18.77
43.	Papaya	25.07	43.	Cotton	18.50
44.	Peanuts	24.24	44.	Papaya	18.05
45.	Passion fruit	23.77	45.	Passion fruit	17.20

Source: Prepared by the author

In all cases, the lowest priority groups (35-45) included cotton, peanuts, beets, lettuce, apples, peaches, and passion fruit.

AGRICULTURAL RESEARCH PRIORITIES IN NICARAGUA

Context

In Nicaragua, the ARPs were identified during 1991, when the size of the state was being reduced and the private sector was being encouraged to carry out economic activities in new areas. Research and extension activities were being decentralized; whereas these activities had previously been centralized in the Dirección General de Tecnología Agropecuaria (DGTA) of the Ministry of Agriculture (MAG), when they were decentralized, physical and human resources were reassigned to national commissions.

These commissions, which specialize in developing certain categories of products, are tripartite agencies (made up of representatives of the private sector, workers, and the government) and have considerable autonomy as regards decision making. The names of the commissions are Comisión Nacional de Alimentos Básicos (National Commission on Basic Foods), Comisión de Productos Tradicionales de Exportación (Commission on Traditional Export Commodities) and Comisión de Productos No Tradicionales de Exportación (Commission on Nontraditional Export Commodities). In addition, the following public sector institutions were carrying out formal research programs: Centro Nacional de Investigación en Granos Básicos (National Center for Research on Basic Grains–CNIGB) and Dirección de Extensión Rural (Directorate of Rural Extension–DER).

During this decentralization process, the Fondo de Desarrollo Tecnológico (Technology Development Fund–FDT), an agency of the Ministry of Agriculture (MAG), was responsible for distributing among the national agricultural commissions the revenues from a 2% tax on production, for research and technology transfer activities.

It is not easy to develop a model for the allocation of resources to research among and within commissions. Some "simple" solutions have been proposed, such as the consistency model (Ruttan 1982), which consists of allocating research resources to each product directly in proportion to its contribution to total revenues from the aforementioned tax. This type of solution, however, usually does not maximize social benefits.[1] The more complex solutions, such as the application of linear programming models for allocating a given budget among projects, are costly and require highly trained human capital (Medina Castro 1991a). The alternative presented here as a preliminary proposal is to organize categories of research according to predetermined objectives.

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1 According to economic theory, in order to maximize social benefit, funds should be allocated in such a way as to ensure that the marginal benefit per peso (córdoba) invested in research is equal for each product. It is highly unlikely that the consistency model would provide for this optimum allocation.

Methodology

Based on the report entitled *El desafío del sector agropecuario: Lineamientos para la reactivación* (The Challenge of the Agriculture Sector: Guidelines for Reactivation), certain research priorities by product were identified. One of the purposes was to embark on a process of change in the economic structure of the agriculture sector that would allow for maximum use to be made of the production potential of the country within a context of economic efficiency, social equity, and sustainable use of natural resources (MAG 1990:2).

Two objectives were considered in setting priorities for agricultural research in Nicaragua, namely, efficiency and equity. The list of products suggested by MAG officials is shown in Table 16.

Table 16. Nicaragua: Products proposed as priorities for agricultural research.

1. Corn	11. Chiltoma	21. Sugarcane	31. Pumpkin
2. Beans	12. Beets	22. Citrus fruits	32. Pejibaye
3. Rice	13. Cucumbers	23. Pineapple	33. Coconut
4. Sorghum	14. Chayote	24. Avocado	34. Annatto
5. Cabbage	15. Cotton	25. Papaya	35. Cassava
6. Tomatoes	16. Sesame	26. Passion fruit	36. Tiquisque
7. Garlic	17. Soybeans	27. Mangoes	37. Plantains
8. Onions	18. Peanuts	28. Pitahaya	38. Bananas
9. Asparagus	19. Cacao	29. Cantaloupe	39. Forestry products
10. Carrots	20. Coffee	30. Watermelon	40. Dual-purpose cattle

Source: Prepared by the author.

While some of the information on variables pertaining to categories of production for 1990 and 1991 was obtained from local secondary sources and FAO yearbooks, most of it was obtained from interviews with MAG officials and officials of the national commissions, the Central American University (UCA), CNIGB, and the Instituto Nicaragüense de Recursos Naturales (Nicaraguan Institute of Natural Resources–INRENA). These interviews were conducted in order to determine values for the following variables: comparative advantage, number of farmers, self-consumption, calories, and proteins in the daily diet. The weighting factors for the variables described in Table 17 were determined through interviews with researchers and administrators in MAG and the national commissions.

Table 17. Weighting factors and quantitative and qualitative variables.

Variables	Weighting factors*
Quantitative	%
1. Value of production	11
2. Value of international trade	8
3. Anticipated change in demand	5
4. Comparative advantage (DCR)	11
5. Number of farmers	12
6. Level of self-consumption	3
7. Calories provided in average daily diet	4
8. Proteins provided in average daily diet	5
Qualitative	
9. Seriousness of problems to be solved through research	8
10. Private-sector incentives	3
11. Current research emphasis	4
12. Use of and savings in resources (manpower and land)	10
13. Information flows to and from international centers	4
14. Research potential (anticipated increase in yields)	11

* The sum of weighting factors is not 100%, as rounded figures are used.

Source: Prepared by the author.

Results

Two types of priorities were identified: (1) for all agricultural products considered, and (2) for nontraditional export products. The priorities established are shown in Table 18.

In the first exercise–priorities for all categories of products–the first ten places included staple foods (rice, beans, corn, sugarcane, and dual-purpose cattle), traditional export commodities (coffee and sugar) and some nontraditional export commodities (pineapple and cacao). This ranking is consistent with the goals set forth in the report entitled *El desafío del sector agropecuario* (MAG 1990), which suggests increasing production of staple foods should be promoted in order to promote food security, as well as traditional and nontraditional export commodities.

Evidently, the priorities identified depend partly on the values of the weighting factors. In this case, the researchers and administrators interviewed placed greater emphasis on variables pertaining to economic efficiency (65%) than on variables pertaining to equity (34%).

A change in weighting factors would probably indicate high priority for staple foods, inasmuch as the partial scores were high with almost all the variables.

Table 18. Nicaragua: Research priorities.

Agricultural products

Priority	Product	Score
1.	Bananas	40.59
2.	Cattle (dual-purpose)	36.88
3.	Coffee	34.34
4.	Beans	33.98
5.	Corn	33.07
6.	Rice	32.18
7.	Sugarcane	31.41
8.	Pineapple	30.48
9.	Cotton	30.31
10.	Cacao	30.18
11.	Bananas	29.93
12.	Sorghum	29.27
13.	Plantains	29.12
14.	Citrus fruits	29.01
15.	Pitahaya	28.73
16.	Sesame	28.20
17.	Onions	27.33
18.	Mangoes	27.23
19.	Cantaloupe	27.08
20.	Tomatoes	26.71
21.	Cabbage	26.67
22.	Garlic	25.71
23.	Forestry products	25.70
24.	Cassava	25.3
25.	Annatto	23.82
26.	Avocado	23.71
27.	Tiquiste	23.20
28.	Papaya	23.02
29.	Chiltoma	22.53
30.	Chayote	22.48
31.	Passion fruit	21.58
32.	Watermelon	21.54
33.	Peanuts	21.44
34.	Carrots	21.37
35.	Pumpkin	21.18
36.	Beets	21.13
37.	Coconut	20.85
38.	Pejibaye	20.73
39.	Cucumbers	19.75
40.	Soybeans	18.30
41.	Asparagus	17.59

Nontraditional export commodities

Priority	Product	Score
1.	Pineapple	23.22
2.	Cacao	22.42
3.	Citrus fruits	22.22
4.	Plantains	21.94
5.	Pitahaya	21.36
6.	Onions	21.11
7.	Cantaloupe	20.67
8.	Mangoes	20.61
9.	Tomatoes	20.58
10.	Cabbage	20.54
11.	Garlic	19.76
12.	Cassava	19.62
13.	Avocado	17.73
14.	Annatto	17.68
15.	Chiltoma	17.65
16.	Tiquisque	17.31
17.	Chayote	17.28
18.	Papaya	17.21
19.	Watermelon	16.93
20.	Pumpkin	16.70
21.	Carrots	16.65
22.	Beets	16.41
23.	Passion fruit	16.33
24.	Coconut	15.61
25.	Pejibaye	15.49
26.	Cucumbers	15.27
27.	Asparagus	12.53

Source: Prepared by the author.

Priorities Identified for Nontraditional Products

Table 18 shows the priorities assigned to the nontraditional export commodities. It should be noted that the order of importance changes as the list of products to be ranked is changed. Thus, priorities for nontraditional products, when included along with all other categories of products, are not necessarily the same as those obtained with nontraditional products are considered separately. In the overall ranking, for example, plantains have higher priority than citrus fruits; this order is reversed, however, when only nontraditional products are considered.

AGRICULTURAL RESEARCH PRIORITIES IN PANAMA

Context

Within the NARS in Panama, which includes both public and private institutions concerned with agricultural research, two institutions are engaged in generating final-product technology: the Instituto de Investigación Agropecuaria de Panamá (Panamanian Agricultural Research Institute–IDIAP) and the Facultad de Ciencias Agronómicas (Faculty of Agronomic Sciences–FACA) of the University of Panama. Thus, research is concentrated in two institutions, while resources are scarce. This, coupled with the rich biological diversity of the country, means that only a few products, from a wide range, can be chosen for research purposes (Cuéllar 1990).

Given the public nature of both institutions, research resources must be assigned with a view to maximizing social benefit. Hence, a number of different agricultural products have been ranked in order to provide useful information for the allocation of resources, so that research can be conducted in accordance with Panama's agricultural policy. In addition, this priority-setting exercise may be the first step in improving the allocation of research resources among specific categories of products.

Methodology

The list of products for which priorities were established in shown in Table 19.

The general objectives of agricultural policy established by the Panamanian Ministry of Agricultural Development (MIDA 1991) are the following:

— To contribute toward raising living standards in general.
— To promote comprehensive development of farmers and their families.
— To reactivate the economy of the agriculture sector.

In line with this policy, three objectives were considered in setting priorities for agricultural production in Panama: efficiency, equity, and sustainability. The variables associated with these objectives are shown in Table 20.

Table 19. Panama: Products proposed as priorities for agricultural research.

1. Rice	12. Sugarcane	22. Coffee	33. Beef cattle
2. Corn	13. Onions	23. Bananas	34. Dairy cattle
3. Sorghum	14. Lettuce	24. Plantains	35. Swine
4. Beans (Frijol)	15. Pimentón	25. Coconut fruit	36. Chickens (meat)
5. Beans (Porotos)	16. Cabbage	26. Oranges	37. Chickens (eggs)
6. Soy beans	17. Tomatoes (table)	27. Cacao	38. Beets
7. Guandú	18. Tomatoes (industrial)	28. Avocado	39. Chayote
8. Cassava		29. Papaya	40. Garlic
9. Ñame	19. Carrots	30. Pineapple	
10. Potatoes	20. Cucumbers	31. Citrus fruits	
11. Otoe	21. Watermelon	32. Mangoes	

Source: Prepared by the author.

With regard to the weighting factors for the variables considered, in the case of Panama, three scenarios were envisaged, as shown in Table 20. In scenario 1, the weighting factors were obtained through interviews with administrators and researchers. The weighting factors for scenario 2 were chosen with a view to ascertaining how priorities change when the research policy stresses the equity objectives; in scenario 3, the emphasis was on economic efficiency.

Results

The results of the exercise are shown in Tables 21 and 22. The following analysis is not exhaustive. The 41 products were divided into four groups: one group with 11 products and three with 10 products each, according to the following order of priority: very high, high, medium, and low.

Scenario 1

The highest priority group (1-11) included traditional export commodities (beef cattle, bananas, and sugarcane) and products that are significant in the diet of the Panamanian population (milk, chicken, plantains, beef, sugarcane, and ñame). Rice, which is the main staple in Panama, was not ranked high in priority for research purposes. The lowest priority group is mainly made up of vegetables.

A comparison between this exercise and the priority-setting exercise in other countries, such as El Salvador, shows that in Panama, rice and beans are assigned lower priority, whereas in El Salvador, staple grains (corn, beans, rice, and sorghum) are ranked in the first four places.

Table 20. Panama: Quantitative and qualitative variables considered in setting priorities for categories of agricultural production.

Variables	SCENARIO 1	SCENARIO 2	SCENARIO 3
	Weighting factors obtained through interviewe	**Emphasis on equity: weighting total 70%**	**Emphasis on efficiency: weighting factors associated with importance of theproduct total 6%**
	(weighting factors)	**(weighting factors)**	**(weighting factors)***
Quantitative			
1. Value of production	9	3	14[2]
2. Value of international trade	5	3	14[2]
3. Anticipated change in demand	4	3	14[2]
4. Comparative advantage (DCR)	9	3	14[2]
5. Research experience	6	3	4
6. Number of farmers	8	14	4
7. Level of self-consumption	6	14[1]	4
8. Calories provided in average daily diet	4	14[1]	4
9. Proteins provided in average daily diet	3	14[1]	4
Qualitative			
10. Seriousness of problems to be solved through research	10	3	4
11. Private sector incentives	5	3	4
12. Technologies not harmful to environment	9	3	4
13. Impact on employment	9	14[1]	4
14. Information flows to and from international centers	4	3	4
15. Research potential (anticipated increase in yields)	9	3	4

* The sum of weighting factors is not 100% because rounded figures are used.

1. Variables associated with the equity objective.
2. Variables associated with economic importance of the product.

Source: Prepared by the author.

Table 21. Panama: Research priorities under scenarios 1 and 2.

Scenarios 1			Scenarios 2 (emphasis on equity)		
Priority	Product	Score	Priority	Product	Score
1.	Plantains	34.55	1.	Cattle (dairy)	34.77
2.	Cattle (beef)	33.01	2.	Plantains	34.30
3.	Cassava	32.45	3.	Cattle (beef)	33.28
4.	Coffee	31.89	4.	Cassava	32.92
5.	Ñame	31.47	5.	Corn	32.33
6.	Sugarcane	30.84	6.	Rice	32.27
7.	Chicken (meat)	30.55	7.	Chicken (meat)	31.88
8.	Cattle (dairy)	30.27	8.	Bananas	31.63
9.	Bananas	30.05	9.	Ñame	31.30
10.	Tomatoes (indust.)	8.49	10.	Sugarcane	31.04
11.	Paprika	28.46	11.	Beans (porotos)	29.51
12.	Onions	28.41	12.	Chicken (eggs)	29.12
13.	Coconut	28.37	13.	Beans (frijol)	28.86
14.	Oranges	28.00	14.	Coffee	28.62
15.	Papaya	27.65	15.	Coconut	28.21
16.	Otoe	27.29	16.	Swine	28.06
17.	Corn	27.15	17.	Otoe	26.70
18.	Mangoes	26.92	18.	Oranges	26.54
19.	Lettuce	26.91	19.	Mangoes	25.33
20.	Rice	26.67	20.	Onions	24.74
21.	Chicken (eggs)	26.63	21.	Avocado	24.41
22.	Cantaloupe	26.55	22.	Guandú	24.16
23.	Tomatoes (table)	26.48	23.	Cacao	24.14
24.	Avocado	26.45	24.	Pineapple	23.90
25.	Swine	26.38	25.	Paprika	22.88
26.	Beans (porotos)	26.02	26.	Citrus fruits	22.43
27.	Beans (frijol)	25.94	27.	Papaya	22.35
28.	Pineapple	25.34	28.	Tomatoes (industrial)	22.20
29.	Cacao	25.09	29.	Potatoes	22.10
30.	Citrus fruits	24.75	30.	Lettuce	21.37
31.	Garlic	24.61	31.	Tomatoes (table)	21.21
32.	Cabbage	24.59	32.	Watermelon	19.44
33.	Watermelon	24.56	33.	Cucumbers	18.56
34.	Cucumbers	24.24	34.	Soybeans	18.54
35.	Carrots	23.56	35.	Garlic	18.43
36.	Potatoes	22.93	36.	Cabbage	18.41
37.	Beets	21.94	37.	Cantaloupe	18.05
38.	Guandú	21.75	38.	Carrots	17.30
39.	Chayote	21.48	39.	Sorghum	17.18
40.	Sorghum	20.54	40.	Beets	16.29
41.	Soybeans	17.87	41.	Chayote	15.87

Source: Prepared by the author.

Table 22. Panama: Research priorities under scenarios 1 and 3.

Scenarios 1			Scenarios 3 (emphasis on economic significance of product)		
Priority	**Product**	**Score**	**Priority**	**Product**	**Score**
1.	Plantains	34.55	1.	Cattle (dairy)	33.54
2.	Cattle (beef)	33.01	2.	Plantains	33.16
3.	Cassava	32.45	3.	Bananas	32.66
4.	Coffee	31.89	4.	Coffee	31.20
5.	Ñame	31.47	5.	Sugarcane	30.66
6.	Sugarcane	30.84	6.	Cattle (dairy)	30.18
7.	Chicken (meat)	30.55	7.	Chicken (meat)	30.12
8.	Cattle (dairy)	30.27	8.	Coconut	28.92
9.	Bananas	30.05	9.	Ñame	28.92
10.	Tomatoes (indust.)	28.49	10.	Beans (frijol)	27.42
11.	Paprika	28.46	11.	Tomatoes (industrial)	27.40
12.	Onions	28.41	12.	Beans (porotos)	26.26
13.	Coconut	28.37	13.	Cantaloupe	26.02
14.	Oranges	28.00	14.	Paprika	25.68
15.	Papaya	27.65	15.	Corn	25.54
16.	Otoe	27.29	16.	Onions	25.46
17.	Corn	27.15	17.	Papaya	25.42
18.	Mangoes	26.92	18.	Chicken (eggs)	25.40
19.	Lettuce	26.91	19.	Lettuce	25.34
20.	Rice	26.67	20.	Cassava	25.32
21.	Chicken (eggs)	26.63	21.	Oranges	24.62
22.	Cantaloupe	26.55	22.	Cabbage	23.98
23.	Tomatoes (table)	26.48	23.	Rice	23.82
24.	Avocado	26.45	24.	Garlic	23.80
25.	Swine	26.38	25.	Swine	23.76
26.	Beans (porotos)	26.02	26.	Potatoes	23.70
27.	Beans (frijol)	25.94	27.	Pineapple	22.26
28.	Pineapple	25.34	28.	Sorghum	21.78
29.	Cacao	25.09	29.	Tomatoes (table)	21.74
30.	Citrus fruits	24.75	30.	Otoe	21.66
31.	Garlic	24.61	31.	Watermelon	21.44
32.	Cabbage	24.59	32.	Avocado	21.40
33.	Watermelon	24.56	33.	Guandu	21.28
34.	Cucumbers	24.24	34.	Cacao	21.18
35.	Carrots	23.56	35.	Beets	20.92
36.	Potatoes	22.93	36.	Carrots	20.44
37.	Beets	21.94	37.	Cucumbers	20.40
38.	Guandú	21.75	38.	Mangoes	20.20
39.	Chayote	21.48	39.	Soybeans	19.00
40.	Sorghum	20.54	40.	Citrus fruits	18.32
41.	Soybeans	17.87	41.	Chayote	17.12

Source: Prepared by the author.

Scenario 2

As expected, when the weighting factors used in scenario 1 were biased toward variables associated with equity, almost all the products in the basic food basket (low-demand elasticity according to income) were included in the highest priority group. Beans also ranked higher than under scenario 1.

Scenario 3

When the weighting factors were changed to emphasize the economic efficiency objective in terms of the importance of the product, all the traditional export commodities (bananas, sugarcane, coffee, and beef cattle) were included in the highest priority group; coconut, which is one of the nontraditional export commodities, is also included in this group. Cantaloupe, which in 1990 was the main nontraditional export product, increased in priority in scenario 3 with respect to scenario 1.

In all three scenarios, the highest priority groups include plantains, bananas, beef cattle, dairy cattle, chicken meat, sugarcane, and ñame. This result is probably due, *inter alia,* to the following: (a) these products are significant in the diet of the Panamanian population, (b) they are important export commodities, or (c) they have a high production value, as in the case of chicken meat. This latter result is compatible with a priority-setting exercise carried out by IDIAP in 1988, which showed these 7 products among the 11 highest places in a list of 25 products (IDIAP 1988)

GENERAL CONSIDERATIONS

Priorities in the Central American Countries

Although the priority-setting exercises were carried out at different times (1990-92) in the different Central American countries, a comparison of priorities among the countries under the different scenarios shows a pattern throughout the region as regards those products to which high priority is assigned for research purposes. This pattern might or might not be confirmed if priority-setting exercises were to be conducted simultaneously in all the Central American countries, using the same variables and weighting factors.

Nevertheless, a look at the categories that fell within the first ten places in all the countries (Table 23) gives rise to the following observations:

— Traditional export commodities (coffee, beef and dairy cattle, bananas, and sugarcane) are ranked in the first ten places in every country, except for sugarcane in Honduras.

— Basic grains, especially rice, corn, and beans, have very high priority in four Central American countries (Guatemala, El Salvador, Honduras, and Nicaragua), where they are the main source of calories and proteins for the population (Cáceres and Murillo 1991).

— Tomatoes, plantains, and potatoes are among the products that have highest priority in the region. Roots and tubers are important in Costa Rica and Panama.

— In Costa Rica, high priority is assigned to nontraditional export commodities (oranges, plantains, cantaloupe, and roots and tubers). In El Salvador, nontraditional export products were not considered to have priority for research purposes.

Reallocation of Resources toward the Priorities Identified

It is not always profitable over the short term to reallocate resources toward the priorities identified. Cumulative research experience with a given product or discipline is the result of investments that to some extent are irreversible, inasmuch as they represent sunken costs that cannot be completely recovered (Pindyck 1991). Moreover, it takes a considerable investment in human (training, generation of know-how) and physical resources to mobilize resources for a specific product or discipline. The cost of mobilizing resources between products or disciplines depends on the relationship between them, as regards know-how and the types and amounts of resources to be mobilized. In this regard, it is not always feasible to implement the priorities identified over the short term.

In the case of Guatemala, for example (Table 11), sugarcane was ranked fifth, but the human resources (in terms of researcher-years) devoted to that product are in twenty-second place. By contrast, cabbage was assigned thirteenth place, but in terms of researcher-years, it ranks eighteenth. Thus, *ceteris paribus,* it would be less costly over the same period to increase the human resources devoted to research on cabbage, that is, to go from eighteenth place to thirteenth place, than it would be to increase resources for sugarcane, which requires moving from twenty-second to fifth place.

Similarly, whether or not it is feasible to implement the research priorities (by product) identified in the Central American countries will depend on the priority that has traditionally been given to the categories in question, in terms of the research resources devoted to them. Over the short term, it would probably be easier and less costly to use the existing structure to increase resources for research on the traditional export products and staple grains, than it would be to increase research on new, nontraditional export products, such as oranges in Costa Rica and pineapple in Nicaragua.

Evidently, over the medium and long terms, and depending on the international economic context and the development style considered, it could be more profitable to mobilize research resources toward nontraditional export products than it would to maintain the existing ratio between resources devoted to research on traditional products, nontraditional export products, and staple foods.

Table 23. Central America: Agricultural research priorities by product.

Priority	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama
1.	Bananas	Corn	Coffee	Bananas	Bananas	Plantain
2.	Oranges	Beans	Bananas	Coffee	Coffee	Beef cattle
3.	Cantaloupe	Rice	Tomatoes	Corn	Beans	Cassava
4.	Plantains	Sorghum	Potatoes	Dual-p. cattle	Corn	Coffee
5.	Cattle (beef)	Coffee	Sugarcane	Plantains	Rice	Yam
6.	Cattle (dairy)	Sugarcane	Dual-p. cattle	Potatoes	Sugarcane	Sugarcane
7.	Coffee	Cattle (dairy)	Whea	Beans	Pineapple	Chicken (meat)
8.	Sugarcane	Cattle (beef)	Corn	Tomatoes	Cotton	Cattle (dairy)
9.	Potatoes	Tomatoes	Beans	Rice	Cacao	Bananas
10.	Roots and tubers	Bananas	Cardamom	Mangoes	Bananas	Tomatoes (ind.)
11.	Poultry	Papaya	Cotton	Soybeans	Sorghum	Pimenton
12.	Strawberries	Poultry	Carrots	Cacao	Plantains	Onions
13.	Mangoes	Swine	Cabbage	Citrus fruits	Citrus fruits	Coconut
14.	Pineapple	Plantains	Broccoli	Poultry	Pitahaya	Oranges
15.	Cassava	Lumber	Cauliflower	Cantaloupe	Sesame	Papaya
16.	Tomatoes	Honey	Rice	Watermelon	Onions	Otoe
17.	Cacao	Potatoes	Bell peppers	Pineapple	Mangoes	Corn
18.	Papaya	Eggs	Onions	Sorghum	Cantaloupe	Mangoes
19.	Swine	Coconut	Cucumbers	Cabbage	Tomatoes	Lettuce
20.	Chayote	Pineapple	Asparagus	Swine	Cabbage	Rice
21.	Corn	Oranges	Forestry prod.	Garlic	Garlic	Chicken (eggs)
22.	Soursop	Lemons	Plantains	Goats	Forestry prod.	Cantaloupe
23.	Passion fruit	Avocado	Citrus fruits	Avocado	Cassava	Tomatoes (table)
24.	Blackberries	Cantaloupe	Tobacco	Cassava	Annatto	Avocado
25.	Beans	Cabbage	Sweet potatoes	Sugarcane	Avocado	Swine
26.	Bell peppers	Onions	Apples	Forestry prod.	Tiquisque	Beans (poroto)
27.	Macadamia	Watermelon	Lettuce	Grapes	Papaya	Beans (frijol)
28.	Onions	Carrots	Peaches	Onions	Chiltoma	Pineapple
29.	Avocado	Sesame	Cantaloupe	Pumpkin	Chayote	Cacao
30.	Cabbage	Chile	Pears	Sesame	Passion fruit	Citrus fruits
31.	Rice	Soybeans	Sorghum	Chile	Watermelon	Garlic
32.	Lumber	Cucumbers	Cacao	Coconut	Peanuts	Cabbage
33.	Pejibaye	Mangoes	Citronella	Cucumbers	Carrots	Watermelon
34.	Carrots	Peanuts	Watermelon	Afric. palm	Pumpkin	Cucumber
35.	Lettuce	Cotton	Mangoes	Apples	Beets	Carrots
36.	Broccoli	Lettuce	Lemon tea	Cashew	Coconut	Potatoes
37.	Afric. palm	Cashew	Papaya	Tamarind	Pejibaye	Beets
38.	Asparagus	Hemp	Okra	Cotton	Cucumbers	Guandú
39.	Cauliflower		Cashew	Carrots	Soybeans	Chayote
40.	Watermelon		Peanuts	Peaches	Asparagus	Sorghum
41.	Orn. plants		Sesame	Beets		Soybeans
42.	Tobacco		Grapes	Lettuce		
43.	Cucumbers		Soybeans	Papaya		
44.	Flowers			Peanuts		
45.	Pepper			Passion fruit		
46.	Cotton					
47.	Soybeans					
48.	Sorghum					

Source: Prepared by the author.

FINAL REMARKS

The scoring method used for this study makes it possible, among other things, to analyze–in small countries, at the macro level, in a practical and economical way–the importance of certain categories of agricultural production with a view to concentrating efforts and allocating resources for research within the public sector. The method applied can easily be changed in order to determine the importance of products from other viewpoints, such as self-sufficiency in food production or promotion of exports.

In the cases of Costa Rica, Honduras, and Panama, the use of a number of scenarios consisting of different sets of weighting factors that can be interpreted as parameters for defining research policy makes it possible to identify and rationalize different types of priorities for the categories of agricultural production.

It should be noted that setting priorities for research by product, at the country level, can be interpreted differently depending on the socioeconomic context, the structure of NARS, and the objectives proposed. In addition, when different scenarios are used, the priorities identified provide information that is useful for decision making: for example (a) how to orient a NARS, as suggested in the case of Honduras; (b) research options that might be transferred to the private sector, as in the case of Guatemala; and (c) research on nontraditional export commodities that should be emphasized, and the reasons why, as in the case of Nicaragua.

The scoring method used allows only for a distinction to be made regarding the importance of one product with respect to another, in accordance with the objectives and the variables chosen, but it is not a tool for measuring the amount of resources that should be allocated for research on individual products.

There are other ways to allocate resources in order to achieve certain objectives in a more precise and specific manner. Some options might be (a) to cross the priorities obtained with other variables, such as supply of and demand for technology, which would make it possible to determine if it is necessary to invest in increasing the supply of technology or the transfer of technology; (b) to carry out a second priority-setting exercise with respect to research projects for a group of priority products, using cost-benefit techniques; and (c) to carry out a second priority-setting exercise with respect to disciplines within certain priority products.

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APPENDIX

Crops on Which Research Is Being Conducted by Public Agencies in Central America.

	Costa Rica (1991)	El Salvador (1990)	Guatemala (1991)	Honduras (1991)	Nicaragua (1990)	Panama (1990)
Programs	**MAG**	**CENTA**	**ICTA**	**DNIA**	**CNIGB**	**IDIAP**
Crops	Basic grains Oilseeds Production of forage seeds Roots and tubers Fruit trees Bananas Sugarcane	Corn Beans Rice Sorghum Vegetables Fruit trees	Corn Beans Rice Sorghum Wheat Oilseeds Vegetables Fruit trees Medicinal plants	Corn Beans Rice Sorghum Oilseeds Vegetables	Corn Beans Rice Sorghum	Basic grains Vegetables Roots and tubers Export crops Pastures
Livestock:	Cattle		Cattle (dual purpose) Small species			

Source: Prepared by the author.

Chapter 6

METHODOLOGICAL DEVELOPMENT OF A PRIORITY SETTING MODEL FOR AGRICULTURAL RESEARCH SYSTEMS FOR PROCISUR MEMBER COUNTRIES

FINAL REPORT

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INTRODUCTION

Background

The dynamics of the changes taking place in agriculture today are very different from those of comparable situations in the past, inasmuch as they involve all the sectors engaged in the activity simultaneously. The national and international institutions responsible for agricultural technology generation and transfer are faced with a new challenge: they must try to fulfill the function for which they were created even as the very legitimacy of their task and the likelihood of their being able to perform it under radically different conditions are being called into question. The past is an increasingly unreliable source of inspiration as far as the determination of action strategies is concerned, the present is characterized by confusion, and the future appears more uncertain than ever.

The obstacles to research and the problems it faces under such conditions are magnified by the scale and importance of the activity in Latin America and the Caribbean (LAC). It can no longer be regarded as an activity of secondary importance, with more than 10,000 researchers involved throughout the region. A few decades ago research was conducted exclusively by Ministries of Agriculture via institutes and departments created specially for the purpose. Today the work is carried out by a host of different institutions. Apart from the ones already mentioned, they include international and regional centers, universities, foundations, private sector, and mixed centers, plus other public sector entities and centers. At least US$600 million a year are plowed into research of this kind. Last but not least, research has a considerable impact on the region: a number of studies (Rodrigues da Cruz et al. 1982; Norton et al. 1987; Echeverría 1990) have concluded that these resources generate major benefits for agriculture in the region.

The really important issue is the future, however. Technology and know-how requirements have mushroomed and changed radically, creating new objectives and challenges for researchers. These include making agriculture a sustainable activity by preserving natural resources for future generations; ensuring the competitiveness of the countries and the region as a whole in increasingly open markets; fostering a broad-based, equitable distribution of the benefits; offering products that meet the quality and safety standards demanded by consumers; and, in order to achieve all the above, taking advantage of the new scientific and technological revolution. The mushrooming needs of agriculture are also due to diversification into new fields. Whereas in previous decades only certain commodities and agroecological zones received systematic attention, the broadening and deepening of the market economy makes diversity a competitive advantage. A rapidly growing number of fruits, vegetables, nuts, spices, ornamental plants, and animals are now being produced on a commercial scale, and technology tailored to the needs of the various agroecological zones is called for.

Lastly, all the above means that the social sciences are required to contribute additional know-how, and this is largely a question of political-institutional considerations. Research institutions, especially national agricultural research institutions (NARIs) have acknowledged the daunting nature of the task ahead. In different forums, particularly since the 1980s, experts have pointed to the need for a consultative and priority-setting mechanism for the region to help coordinate, manage, and enhance their efforts.

The first step in this direction was the setting up of the Latin American and Caribbean chapter of the International Federation of Agricultural Research Systems for Development (IFARD). Its concerns gained greater prominence toward the end of the decade when the Inter-American Development Bank (IDB) proposed a change in the funding policy of the Consultative Group on International Agricultural Research (CGIAR) for the region. Basically, the idea was that instead of making a lump-sum contribution to the annual budgets of the various centers operating in the region, funds should be channeled into specific projects, the identification and selection of which presupposed a priority-setting process. In order to implement this change, a workshop was held at the Inter-American Institute for Cooperation on Agriculture (IICA) in San Jose from July 4 to 5, 1990. Attended by senior officials from the NARIs, international centers, and the IDB, the meeting recommended that the IDB promote the creation of a consultation mechanism that would permit the countries to discuss and determine research priorities and facilitate the preparation and funding of special projects. This recommendation was put into effect by the bank in 1992 with the signing of the IICA/IDB Agreement on the Identification of Priorities.

Importance and Rationale of the Work

The present system of resource allocation and agricultural research is ill-equipped to meet the challenges that have just been described. Consisting basically of institutional allocations at the country level, it fails to take account of the externalities involved in research with potentially broader applications and for use on a larger scale, the incorporation of which would be viable if institutions and countries were to work together. Furthermore, there are still big limitations and gaps in the existing models and methods of priority setting in terms of both needs and challenges, particularly as far as new interagency uses and mechanisms are concerned. Despite the significant breakthroughs that have been achieved (Evenson 1991), current methods are mainly developed from a single perspective and their academic objectives are too rigid, which limits their usefulness. In such circumstances, a strong case can be made for efforts to equip the region with tools that would make it possible to identify and reach agreement on priority activities, and underpin decision-making.

Objective

This paper sets out to design and test alternative instruments that would enhance the effectiveness of research resource allocation and the process of identifying, quantifying, and characterizing specific, potentially useful areas and opportunities where real institutional capacity (strengths and weaknesses) could be harnessed to carry out the work concerned.

Specifically, every effort was made to ensure that the methodological results would make it possible to do the following:

- Provide accurate, reliable, and comparative data on the institutional capacity (supply) available for conducting research.
- Identify economies of scale with regard to specific agricultural research topics of interest to more than one country, cutting across international frontiers.
- Estimate the social return of alternative strategies for consolidating research activities.
- Make recommendations to policymakers.
- Evaluate the replication of binational experiences in the rest of the region and suggest the kinds of information needed for the methodology to be used correctly.

The proposed methodology consists of modules that can be applied to different topics either separately or in various combinations. Lastly, it is designed in such a way as to be clear in its reasoning and operation, and have broad applications as far as the data requirements, costs, and technique are concerned.

Strategy

The strategy adopted was designed to develop and test the methodology on a limited international scale, sufficient to ensure its full development and generate important substantive results. It was decided to begin the process at the binational level. A team of specialists was set up for this purpose drawn from Argentina's National Agricultural Technology Institute (INTA) and the Brazilian institute of agricultural research (EMBRAPA), supported by IICA's Technology Generation and Transfer Program. The team studied the case of wheat in the two countries. The relative progress made by the respective national efforts in Brazil and Argentina, the existence of strategic planning and priority setting experts, and the project's limited time horizon were important considerations in deciding who should take part in determining the scope and scale of the analysis.

The work entailed meetings of the joint team and the execution of specific tasks in the countries, for which the respective experts and teams were responsible. Four technical meetings of the joint team were held to plan, design, coordinate, and discuss the work, with the last of these being used to prepare the first draft of the final report. EMBRAPA was represented by Elmar Rodrigues da Cruz and Antonio Flavio Días Avila; INTA, by Eugenio J. Cap, who acted as the overall technical coordinator of the work, and Luis F. Macagno; and IICA, by Héctor Medina Castro and Eduardo Lindarte.

Structure of this Report

The results of the work are presented in five additional chapters. Chapter 1 describes and elaborates upon the global methodological approach adopted and its two components: the institutional analysis and the "production of surpluses as a result of the adoption of technology" (PEAT) model. Chapter 2 examines the economic and technological frame of reference of wheat in two countries. This includes a description of international market conditions and trends, national supply and demand, and production systems and the constraints they face. Chapter 3 describes national priorities and identifies areas of common interest, details and discusses the results of the inventory of institutional capacity and the application of the PEAT model, and considers the implications of the results for the organization of wheat research in the two countries and projections for the transnational optimization of resources. Lastly, Chapter 5 contains a series of recommendations for future action with a view to laying the groundwork for a wider application of the approach to other topics, institutions and countries.

ALTERNATIVE METHODOLOGY FOR ESTABLISHING RESEARCH PRIORITIES

Technical Specifications of the PEAT Model

To achieve their objective, the team decided to adapt for use on a multilateral scale, a methodological approach originally developed for use at the national level by the INTA's Strategic Planning Directorate (Cap 1992, 1993).

This tool, known as the PEAT, consists of a mathematical simulation model that makes it possible to assess the impact of a given course of action on the volume of production, and alternative resource allocation strategies on agricultural research. In simple terms, the model measures how much more of a commodity would be produced if specific technologies were to be generated and transferred. When applied to a national system, the results of simulation runs provide data that facilitates resource allocation within the system; it also helps to determine the institutional return on investments in a specific subject matter area. At the multinational level, the results of the model could help pinpoint where resources should be concentrated by assessing the impact of alternative strategies (*ceteris paribus* the other parameters), after incorporating supply into the analysis, in accordance with topics of common interest and a desire to effect economies of scale. The PEAT model deals with issues related to the demand for technology.

The model makes the following assumptions:

— Farmers in agroecologically homogenous zones can be divided into three technological levels (TLs): low (LTL), average (ATL) and high (HTL), based on their methods, inputs, and productivity measured in terms of unit yields (Fig. 1).

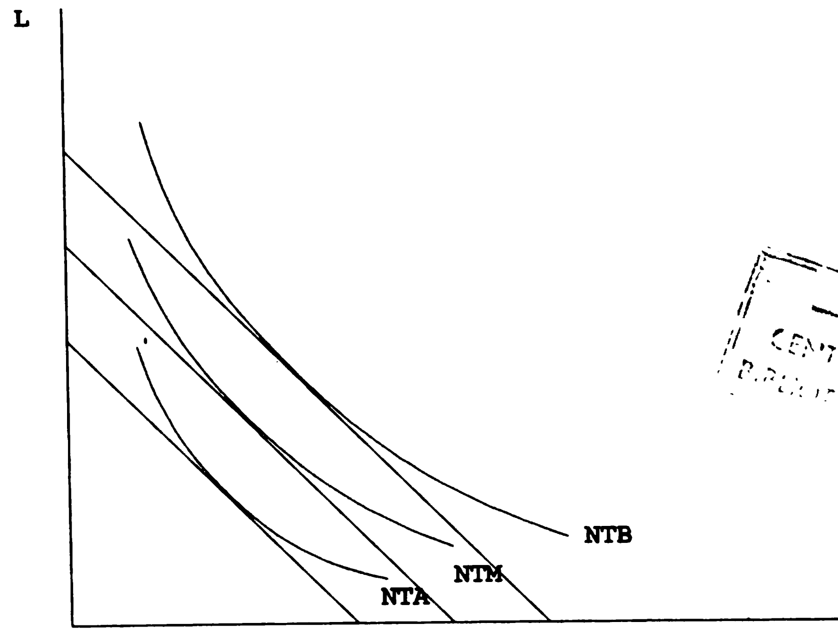

Figure 1. Technological levels between farmers in agroecologically homogenous zones.

Source: Developed by the author.

— There is upward mobility between the TLs due to the gradual incorporation of the methods and inputs available and the ability to use them efficiently. Farmers move up from one technological level to the next. This rate of interlevel movement is the percentage of hectares each year that move up to the next technological level, based on increased productivity. This process is represented by a linear function. There is movement in one direction only; farmers cannot "move down" from a given technological level once they have reached it.

— The national systems (NARIs, universities, etc.) and international centers are in position to generate new technology. Its (future) adoption by farmers is a nonlinear (sigmoid) function, the parameters of which are determined by the nature of the innovation and the socioeconomic profile of the target population of the transfer effort.

Thus, the model's central element is a reconstruction of the process of technology adoption that narrows the gap between the isoquant and the origin (representing them as a combination of inputs and factors); in other words, technologies that result in a more efficient use of resources and, therefore, lower costs. The most important implicit assumption is that the coexistence of the three isoquants or TLs cannot be explained by the use of tools that owe their existence to neoclassical economic theory, given that if farmers were to maximize the benefits, they would all move to the isoquant closest to the origin (HTL). This is not to call into question the rationality of the farmer, but is rather an acknowledgment of the existence of barriers associated with incomplete and/or imperfect markets and constraints to the adoption of the available technology and its optimum use, due to a lack of public (e.g., highway infrastructure), private (e.g., refrigeration facilities or storage facilities), or mixed goods (e.g., the entrepreneurial skills of the farmers concerned and/or the amount of training they have received).

Technology adoption analysis in highly developed countries is based on a premise that highlights the differences with LAC: most farmers operate within a single isoquant. In less-developed agricultural economies, on the other hand, there is a *continuum* of isoquants below the most "advanced" farmers (HTL) further and further away from the point of origin and reaching levels of production inefficiency bordering on economic and social marginality.

The *mobility rate* as defined is understood to be an indicator of the rate of human capital formation in the production sector concerned with the commodity in question. Inputs, and access to information regarding their optimum use, are a precondition for, but not sufficient to effectively attain, the productivity associated with the highest technological level. The acquisition of the necessary know-how (which is not the same as having access to the information) must be accompanied by enhanced business skills, including the capacity to assess risks and the readiness to take them.

A necessarily slow and accumulative process is needed to achieve this, and this is one of the least studied areas of specialized literature, what Hayami and Ruttan (1985) call cultural endowment. This cycle of human capital formation is precisely the reason why interlevel movement occurs in one direction only. Although microeconomic conditions (e.g., poor business decisions) and macroeconomic conditions (e.g., changes in relative price ratios) can lead to lower productivity as a result of less than optimum use of inputs, this does not necessarily reflect a reversal of the process of human capital formation. If the same conditions are reestablished, there should be a rapid return to the previous level of production efficiency. The situation is similar to that of idle capacity in an industry, which increases as a result of a recession and its effect on fixed costs.

The PEAT model is not an alternative to the models proposed in the literature for studying the technology adoption phenomenon, but rather a contribution that is intended to enrich them. It represents an attempt to acknowledge and explain the dynamics of two processes that take place simultaneously. Based on the empirical evidence (Byerlee and Hesse 1982), the adoption of a given technology occurs at a much faster rate than the values associated with interlevel mobility (Cap 1992). The other significant difference between the two processes is their mathematical representation, which is linear for mobility and nonlinear (sigmoid) for technology adoption.

The PEAT model treats the production surplus by commodity (over and above present production) as a function expressed in general terms as follows:

$$E_t = f\left[x_t^d\ [w\ [R\ (Bp)]]\ ,\ x_t^p\ [Y^p(tec^p)\ ,\right.$$

$$\left. p_t\ ((\phi(tec^p), K,\ \alpha(Bp))],\ S(tec^d \in D,\ tec^p)\ ,\ z \right]$$

where:

E_t: Production surplus generated in year t.

x_t^d: Yield increase in year t due to the incorporation of the stock of technology available in t_0.

w: Annual rate of mobility for moving up from one technological level to the next.

R: Constraints to interlevel mobility.

Bp: Supply of public goods (extension, infrastructure, economic policy, etc.)

x^p: Yield increase in year t due to the incorporation of technological innovations ($x^p > 0$ if $t \geq t_d$, where t_d is the year in which the technology becomes available; $x^p = 0$ if $t < t_d$).

Y^p: Potential productivity of new technology.

tec^p: Technology not available (yet to be generated).

tec^d: Technology available.

D: Stock of technologies available.

p_t: Level of adoption of technology not yet available (tec^p) in year t ($p_t > 0$ if $t_d \geq t$).

$ø$: Mean adoption time (50% of farmers have incorporated the innovation).

K: Adoption ceiling, $K \, \varepsilon \, (0.1)$.

α: Constraints to the adoption of a specific technology.

S: Sustainability associated with the technology package, $S \, \varepsilon \, (0.1)$.

z: Vector of random variables.

If the model is formulated in this way, then the problem (P) faced by decisionmakers is the following:

$$(P) \max E_t \text{ (selecting } \mathbf{Bp}, \mathbf{tec^p}\text{)}$$

subject to constraints (budgetary, for example)[1]

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1 This problem of optimization must be dealt with using a piecemeal/"second best" approach, as neoclassical economic analysis is impracticable due to the violation of its fundamental principles. One viable alternative is to use benefit/cost indicators (or IRRs) by restriction of the interlevel mobility for the stock of technology available and by subject matter area for the technologies that are not yet available.

For this theoretical model, as E_t approaches its maximum value from the "left," the partial derivatives shown below are associated to a sign (> or <) consistent with the model's explicit or implicit assumptions[2].

$$1.\quad \frac{\partial E_t}{\partial x^d} \times \frac{\partial x^d}{\partial w} \times \frac{\partial w}{\partial R} \times \frac{\partial R}{\partial Bp} > 0$$

$$2.\quad \frac{\partial E_t}{\partial x^p} \times \frac{\partial x^p}{\partial y^p} > 0$$

$$3.\quad \frac{\partial E_t}{\partial x_p} \times \frac{\partial x_p}{\partial p} \times \frac{\partial p}{\partial \phi} < 0$$

$$4.\quad \frac{\partial E_t}{\partial x_p} \times \frac{\partial x_p}{\partial p} \times \frac{\partial p}{\partial K} > 0$$

$$5.\quad \frac{\partial E_t}{\partial x_p} \times \frac{\partial x_p}{\partial p} \times \frac{\partial p}{\partial \alpha} \times \frac{\partial \alpha}{\partial Bp} > 0$$

$$6.\quad \frac{\partial E_t}{\partial S} \geq 0 \ \ si \ \ S=1;$$

$$> 0 \ \ si \ \ S<1$$

In order to adapt the methodological approach described to the conditions set forth in the joint INTA-EMBRAPA study, certain changes had to be made to the original formulation, while retaining its core elements. Due to time constraints, no inventory of the constraints to adoption in Brazil was carried out, so that variable ***R*** disappears from the formula. The same is true of the variable associated with the coefficient of correction of the surplus associated with the sustainability (***S***) component, which therefore takes the value 1 and is not included in the simulation runs.

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2 1) $A > x^d > E$; $a > w > E$; $a > Bp < R$
2) $A > x^p > E$; $a > p > E$; $a > \o < p$; $a > K > p$; $a > \alpha < p$
3) $A > Bp < \alpha$
4) $A > S > E$

Empirical Model

The empirical formulation of the EMBRAPA/INTA/IICA PEAT is as follows:

$$VE_T = \sum_{t=0}^{T} \sum_{k=1}^{K} \sum_{i=1}^{3} \Big(\big[[\beta^{d}_{ik} \times ((w_{ik}) \times A_{(i-1)kt})] + [\beta^{p}_{ik} \times (K/(1 + e^{-\alpha(t-\phi_i)}) \times A_{ikt}] \big] \times p_k^{FOB} \Big)$$

where:

- VE_T: Value of the surplus in year T (simulation horizon) expressed in a monetary unit to make it possible to add commodities. The net present value (NPV) is obtained by applying the discount rate to the sequence $\{VE_t\}_0^T$.
- t: Year.
- k: Commodity (in this case, $k = 1$).
- i: Technological level $i \varepsilon [1,2,3]$, where: 1=*B*, 2=*M*, 3=*A*.
- β^{dp}: Production gap between yields observed and potential productivity by technology available, by technological level.
- A: Area given over to commodity ***k***.
- β^{p}: Production gap between yields observed and potential productivity by technology not yet available, by technological level.
- K: Potential adoption ceiling (0.1).
- e: Base of neperian logarithms.
- α: Coefficient of correction of the sigmoid curve, associated with constraints to adoption.
- ϕ: Mean adoption time (in years) associated with intrinsic characteristics of a given technology.
- p_k^{FOB}: (Unit) price FOB of commodity k.

Note: The first term of the equation allows us to estimate the increase in production on horizon T due to the adoption of available technology and the optimum use thereof. The second term quantifies the pure effect of technology generation (net social benefit).

The model calls for the following data:

General (descriptive)

- Yield by TL.
- Area by TL.
- Annual rates of interlevel mobility.
- Elasticity of supply (with the data preferably broken down by TL).

Specific (prospective)

- Importance of the problem to be solved or the technological progress to be achieved, e.g., yield losses in kg/ha caused by pests. In this case, there would also have to be information as to the frequency of occurrence.
- Area affected by the problem that would benefit from the technology generated.
- End product if the research project is successful (new state of the art).
- Probability of success.
- Year available.
- Research costs (direct, indirect, and salaries).

Nontraditional Topics/Opportunities

The PEAT model can be applied as designed for "traditional" commodities, that is, those with a history and an area under cultivation. A methodological innovation is required for nontraditional crops, namely technological alternatives that would push back the agricultural frontier, for instance, irrigated wheat in the *cerrados* of Goias, Brazil. For present purposes, the assumption is that the new, alternative technology is introduced without substituting commodities.

The problem of a lack of history (no descriptive analysis is possible) can be solved by using alternative scenarios for t_d (point at which the technology becomes available). Observe the following example:

Potential surface area for growing irrigated wheat: AP ha

t_0 = 1993.

t_d = t_{0+x}, where x represents the estimated time before the technology becomes available.

To execute the simulations, two assumptions have to be made:

1. There will be a single technological level.
2. The adoption will follow a logistical path.

In this way, a matrix of possible scenarios is arrived at. If three scenarios are proposed for ø (mean adoption time) and three for *a* (constraints), this matrix would be as follows:

Values of *a*	**Values of ø in years**		
	3	**5**	**7**
0.5	A	B	C
1	D	E	F
1.5	G	H	I

This matrix of scenarios makes it necessary to carry out new simulations, with **I** being the worst case scenario and **A** the best case scenario.

For the PEAT model for nontraditional topics/opportunities, the most random component is one associated with the analysis of potential benefits, as there is no empirical data to help define a baseline.

The mathematical formulation for this version of the model could be expressed as follows:

$$VB_{t(d+i)} = \{ [(\frac{K}{1 + e^{-\alpha(t(d+i) - \phi)}}) * AP] * Y \} * p^{FOB}$$

where:

$VB_{t(d+i)}$: Gross value of production to the year $d+\beta$.

K: Potential adoption ceiling.

e: Base of the neperian logarithms.

α: Coefficient associated with constraints to the adoption of technology.

ø: Mean adoption time.

AP: Potential area for the application of technology.

Y: Unit yield.

p^{FOB}: FOB price of commodity.

3 In this case, there are no surpluses, given that the technology generated makes the crop possible for only the first time, so that the entire production has to be regarded as a **benefit**.

The algorithm is constructed to calculate the accumulated total of total gross value (VB) in *T* (time horizon of the simulation) as follows:

$$VBParcial_i = VBt_{(d+i+1)} - VBt_{(d+i)}$$

then,

$$VBTotal = \sum_{i=t_d}^{T} VBParcial_i$$

The NPV is calculated applying the discount rate to the sequence $\{VBparcial_i\}_0^T$.

Incorporating Changes in the Cultivated Area Brought About by Variations in the FOB Price into the PEAT Model

The elasticity of supply with price variations is defined as follows:

$$\delta \equiv \Delta Q/\Delta p \qquad (1)$$

where:

δ: Price elasticity.
ΔQ: Percentage variation in volume of supply.
Δp: Percentage variation in price of product.

since:

$$\Delta Q + [(Q_2/Q_1)-1] \qquad (2)$$

where:

Q_2: Volume of supply after a price adjustment.
Q_1: Original volume.

Substituting (2) in (1),

$$\delta = [(Q_2/Q_1)-1] \,/\, \Delta p \qquad (3)$$

Considering that:

$$Q_1 = Y * ha_1 \qquad (4)$$
$$Q_2 = Y * ha_2$$

where:

Y : Average unit yield.
ha_1: Original area given over to the commodity.
ha_2: Area allocated to the commodity, modified by the impact of a change in price.

Substituting (4) in (3),

$$\delta = ([(ha_2)/ha_1] - 1) / \Delta p \quad (5)$$

Resolving Δha : $[(ha_2)/ha_1] - 1$,

$$\Delta ha = (\delta * \Delta p)] \quad (6)$$

The last equation determines the percentage variation in the surface area given over to the crop as a result of a change in its price; it will be used to calculate the difference (+ or -) in the total number of hectares given over to the commodity, assuming that there is no variation in unit yield.

This procedure can be applied differentially to the three technological levels, provided that the data (or an estimate) of the respective elasticities is available.

Calculating the dynamics of the model

In accordance with the theoretical statement, the mechanics for computing the model take account of two dynamics: one at a technological interlevel[4] determined by a set of factors that impact productivity (e.g., capital formation of all kinds), and another at the technological intralevel of the adoption of a specific technology. The two are related by determining the number of hectares that move up from LTL to ATL, and from the latter to HTL.

If Hi_t denotes the total number of **ha** in the stratum TLi (i = B, M, A) in the period ***t***, then for the most general case (i = M) Hi_t is defined by the total number of **ha** in ATL in the previous period, minus those that moved up to the HTL, plus those that moved up from the LTL. Thus,

4 The assumption is that 50% of the hectares that move up to the next technological level do so after adopting the technology that has not yet been generated, whose impact is simulated. The other 50% is composed of those ha that, without having adopted this technology, have sufficient other "merits" to move up a level. As a result, at the start of the simulation run there are not sufficient ha that have adopted technology, so that the "quota" of immigrants consists primarily (> 50%) of ha that have not adopted technology. Toward the end of the process, the situation is reversed.

$$HM_t = (1 - W_M) * HM_{t-1} + W_B * HB_{t-1}$$

where:

W_B: Rate of mobility from LTL to ATL.
W_M: Rate of mobility from ATL to HTL.

On the other hand, if Ei_t denotes the number of **ha** that moved up from TLi to the next level ($i = B, M$) in the period ***t***, $\alpha * Ei_t$ defines the number of **ha** that move up because they adopt technology and $\beta * Ei_t$ denotes those that move up without having adopted technology, then, $\alpha + \beta = 1$.

For the same period and at the same level there are **ha** that move up from a lower TL or move up to a higher TL, or that adopt technology but fail to move up a level. On the other hand, over the same period the same **ha** moves up one TL or adopts (or fails to adopt) new technology.

The crucial equations as far as the dynamics of the model are concerned are those that define the kind of **ha** exist at each TL in the period ***t***: with new technology HNi_t and old technology HAi_t ($i = B, M, A$). One only needs to define HNi_t, given that NAi_t is calculated as the difference between the total number of **ha** and the **ha** with new technology in the stratum ***I***, in the period ***t***.

It is useful to define the following terms for each period ***t***:

Ai_t: **Ha** that adopt technology in the stratum of level ***I***, in the period ***t***.

$CINi_t$: Accumulated number of immigrant **ha** that have adopted technology and move up to the stratum TLi before o in the period ***t***.

INi_t: **Ha** that move up with new technology to the stratum TLi in the period ***t***.

PNi_t: Potential number of **ha** with new technology in the stratum TLi in the period ***t***.

PNi_t is composed of the **ha** that move up to the stratum TLi with new technology, those in the TLi that adopt it in the period ***t***, and those that already had new technology in the period ***t-1***, HNi_{t-1}. Then:

$$PNi_t = Ai_t + INi_t + HNi_{t-1}$$

The following terms also have to be defined:

IAi_t: **Ha** that move up to stratum i with old technology in the period ***t***.

PAi_t: Potential number of **ha** with old technology in level **l**, in the period ***t***.

PAi_t: Composed of the **ha** that move up to stratum TLi with old technology, those that had old technology in the period ***t*-1**, minus those that adopt it in the period ***t***. Then:

$$PAi_t = IAi_t + HAi_{t-1} - Ai_t$$

The key in defining HNi_t is to ensure that, of the total number of **ha** that potentially have new technology, α^*Ei_t move up, and that, of the **ha** that potentially have old technology, β^*Ei_t move up. This is not always possible because, as the adoption curve is sigmoid, the process turns out to be asymmetric, inasmuch as in the first phase of the curve, PNi_t is relatively low and PAi_t, relatively high: therefore, only PAi_t can meet its quota of emigrants (β^*Ei_t).

Subsequently, in the second phase of the curve, the total numbers of potential **ha** even out, and both types fulfill their emigration quota. In the last phase of the adoption curve, PNi_t is relatively high and PAi_t, relatively low, so that only PNi_t meets its quota of emigrants (α^*Ei_t). Lastly, in order to prevent a **ha** from a TL stratum leapfrogging two levels in the same period and to make it "wait in line" before moving up again, the accumulated number of immigrant **ha** with new technology up to the period ***t***, namely, $CINi_t$, must be added to the emigration quota of the **ha** with the potential for adopting new technology.

In view of the above, HNi_t is defined as follows:

Case 1. The number of potential **ha** with new technology do not meet their quota of emigrants.

$PNi_t < \alpha^*Ei_t + CINi_t$. Two subcases must be considered:

a. If $CINi_t < Hi_t$. The accumulated number of immigrants is smaller than the total number of **ha** in *NTi*, which generally occurs in the first phase of the adoption curve. Then, of all the **ha** that potentially have new technology, all those above CIN_t are in a position to emigrate. Then,

$$HNi_t =: CIN_t$$

b. $CIN_t \geq Hi_t$. The potential **ha** do not fulfill their quota and, in addition, the accumulated number of immigrants with new technology is also greater than, or equal to, the total number of **ha** in the TLi stratum, which could occur in the last phase of the adoption curve. Then all the **ha** that remain in the TLi have new technology.

$$HNi_t =: Hi_t$$

Case 2. The number of potential **ha** with new technology meet their quota, plus the accumulated number of immigrants with new technology.

$PNi_t \geq \alpha^*E_t + CINi_t$. Two subcases must be taken into account:

a. $PAi_t \geq \beta^*Ei_t$. The potential **ha** with old technology fulfill their quota of emigrants. Then,

$$HNi_t =: PNi_t - \alpha^*E_t$$

Naturally, $HAi_t = PAi_t - \beta^*Ei_t$ also, and it is a simple matter to prove that in this subcase, $HNi_t + HAi_t = Hi_t$.

b. $PAi_t < \beta^*Ei_t$. The potential **ha** with old technology fail to meet their quota. Then, all those with old technology are allowed to move up and all those that remain in TLi have new technology. Then,

$$HNi_t =: Hi_t$$

The equations for the dynamics of the low technological level (LTL) are the same with $INi_t = IAi_t = CINi_t = 0$.

In the case of the high technological level, $HNi_t + HAi_t$ are defined by the following:

$$HAi_t =: HAi_{t-1} + IAi_t - Ai_t^{5}$$

$$HNi_t =: Ai_t + INi_t + HNi_{t-1}{}^{6}$$

The adoption curve in the TLi stratum ($i = B, M, A$) for each curve is given by the following:

$$S_{it} = Ki_t / (1 + e^{(-ai\,(t-ei))}),$$

therefore,

$$Ai_t = S_{it} - S_{it-1}$$

5 The stock of **ha** with improved technology is composed of those that adopt it in the period t and those that possess technology that are already included in the HTL, plus the **ha** that had new technology in said level in the period *t-1*.

6 The stock **ha** with old technology in the period *t* is composed of those **ha** that had old technology in the period *t-1*, plus those immigrated with old technology in the period *t*, minus those that adopt it during the same period.

Ki_t = 0 for the periods prior to the introduction of the technology, t_0. For subsequent periods, $Ki_t = K$ remains constant for the stratum TLi ($i = B$) and is given by K = the number of ha with old technology in the year prior to the availability of new technology, t_0, in the LTL.

In the average and high TLs, $Ki_t = 0$ for the years prior to the introduction of technology, as of year $t = t_0$, Ki_t is given by the number of ha with old technology in the year prior to the introduction of the technology in the stratum TLi ($i = M, A$). As of year $t = t_0 + 1$, $Ki_t =: Ki_{t-1} + IAi_t$.

Conceptual Aspects of the Analysis of Operating Capacity

Background and objectives

The future institutional, regional, priority-setting mechanism needs a methodology for analyzing operating capacity to underpin the priority setting models (the emphasis of which tends to be on the demand for technology) so that the information generated also includes supply considerations.

An analysis of operating capacity at the cooperative research program (PROCI) level makes it possible to redirect the allocation of resources in their respective service area and thus avoid duplication of research efforts. At the same time, the methodology helps pinpoint operating units that need strengthening and research centers that could provide advisory assistance and technical training for weak systems within the subregion.

An analysis of operating capacity provides financial institutions and donor agencies with information to help them optimize decision-making with regard to the funding of subregional projects.

Basic citeria for analyzing operating capacity

Comparison

For national institutions, research system coordinators such as EMBRAPA, INTA, etc., the operating capacity (OC) indicators were designed specifically to permit comparisons between the different stakeholders in a given system.

Transfer

The method of analyzing OC developed for this exercise is transferable not only to each country, but also to all the subregions of LAC.

Application

The method of analyzing OC was designed to complement any priority setting mechanism, be it congruency (TAC-CGIAR), scoring, economic surplus, or imputation accounting (Evenson 1988; Medina Castro 1991).

International experience suggests that because they were not complemented with a OC component, studies of priorities executed in the past were little more than academic exercises with very few practical applications as far as decisionmakers were concerned. As a result, they were not used at the operational level.

For decision-making purposes, the OC questionnaire was designed to be flexible enough to manage not only commodities but also different levels of aggregation (beginning with agricultural subsectors and expanding to take in subject matter areas and specific projects), so as to make it adaptable to the various types of program areas that exist in the planning systems of the region's agricultural research institutions. The proposed approach furnishes data that facilitate the identification of project profiles based on their correlation with capacities, for example the following:

a. Projects with Operating Capacity (PWOC)

   - National, concentrated
   - National, dispersed
   - Subregional

b. Projects without operating capacity (PWOOC)

   - National
   - Subregional

Transparency

The information compiled from the OC questionnaire can be used to make decision making more transparent, inasmuch as the users (senior research institution managers, members of commissions responsible for evaluating projects, donor agencies, etc.) can have access to simplified versions of the methodology employed.

Specific conceptual aspects of OC analysis

The following components are used as inputs for OC analysis:

- Human resources
- Financial resources
- Physical resources

It also generates information on:

- Technologies generated
- Publications
- Training courses, technical assistance, and so on

Availability of resources

Human resources

The OC questionnaire processes information on the size and composition of HR at the research station and/or center level as an indicator of their potential for generating results.[7]

The next level of the analysis looks at the situation as regards specific commodities, as staff are often not employed full time on them. In order to take account of situations of this kind, the "person-year equivalent" (PYE) concept is used. For example, if there are two researchers working on improvement and one devotes all his/her time to wheat and the other to wheat and corn (dividing his/her time equally between the two), then the total PYE allocated to wheat is 1.5.

The analysis of human resources also examines staff turnover at each research unit in order to gain an understanding of the stability of the resources and their potential from another standpoint. As there are likely to be substantial differences in turnover by training level (B.Sc., M.Sc., or Ph.D.), by seniority, and by researcher specialty, it is useful to keep a record of the turnover of technical staff, classified according to their years of professional experience. In other words, if two M.Sc. researchers with five years' of experience enter the system and two researchers with 20 years' experience leave it, on balance the change, a priori, would appear to be negative for the unit.

Salary levels are another important factor that must be taken into account. In this case, the team decided not to use only the "basic" salary (the cost for the institution) but also the concept of opportunity cost in the researcher's country, which is a more efficient indicator of real income.

If the above information is available, it is possible to generate a more complete characterization of the research institutions and identify elements of the human resource component such as the following:

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7 A distinction should be drawn between "static" and "dynamic" HR. The former shows the potential in the case of activities already underway, while the latter has to do with the possibilities for mobilizing resources toward the priorities identified. There are many cases in which the rigidity of staff allocation (near to zero elasticity) substantially reduces the possibilities of implementing the results of analyses of priorities.

- Distribution of researchers by level of training.
- Proportion of support staff for research.
- Availability of human resources by subject matter area.
- Annual researcher turnover.
- Potential for mobilizing existing staff within a given area with a view to possibly reassigning them to other areas of research.

Physical and operating resources

To ensure that indicators can be compared (especially in the financial component), the following information should be taken into account:

— Exchange rate and degree of distortion with the equilibrium exchange rate (shadow price of the currency). There can be a significant degree of error if the shadow price is not taken into account by comparing costs with a view to reallocating resources between countries.

— The flow of recurrent expenses is not sufficient. The experience of countries like Colombia suggests that at the commodity level the indirect costs are often higher than the recurrent expenses routinely recorded in budgetary accounting. The indirect costs of a research institution/unit with obsolete teams (over 15 or 20 years of service) are lower than those of new research institutions/units, in terms of the writing down of investments in physical capital. One alternative for the purposes of comparison is to convert stocks of physical capital into annual flows of services. With trained researchers, newer centers or research stations would have a higher flow of physical capital services.

The same can be done with the stock of human capital, due to postgraduate training costs, which increase the value of the stock and the average number of years' experience in the NARI. The useful life of a researcher can be estimated by subtracting the average retirement age from the average number of years spent at the institution. The indirect costs of human resources are calculated in a slightly different way, but the overall concept is the same as for the stock of physical capital. The indirect costs of a Ph.D. who graduated 20 years ago are low. On the other hand, these costs are considerably higher in the case of someone who graduated only recently (replenishment of the investment in training).

Current orientation and outputs generated

Orientation of research

The analysis of the research capacity of the institution proposing projects or work programs under a regional program is an additional element for a priority setting resource allocation model for projects of interest to the region as a whole. Therefore, the OC analysis must look at the subject matter areas of recently completed projects, ongoing projects, and those that got underway only recently.

If the institution has previously executed projects in a specific line of work within one of the three main subject matter areas of agricultural research (genetic improvement, plant protection, and crop management), this in itself is an indicator of operating capacity. On the other hand, if the projects proposed focus on a new area of work, this would indicate in principle that there is no specific operating capacity. In this case, other institutional considerations would have to be analyzed, for example, recent additions to staff by subject matter area, the specialty of researchers who recently concluded postgraduate courses, the subject matter areas of new contracts and agreements with other institutions (international centers, universities, etc.).

Outputs generated and technology transfer

Through their different operating units (research centers, stations), agricultural research institutions generate a quantity of results or outputs each year. Those geared more toward adaptive research generate farmer-oriented publications, train extensionists, offer improved seeds, and so on. Units engaged more in basic research generate scientific publications, germ plasm (improved lines, for example), training courses targeted at researchers, and others. Some units encompass the entire gamut of research and generate outputs of various kinds.

Interagency cooperation

Collaborative activities and the sharing of know-how between organizations are an important aspect of an institution's operating capacity in the context of a regional or subregional research program. It is important to have information on advisory services provided (to other countries), contracts for external consultantships, joint work carried out with other research institutions, and coordination with international centers, where they exist, for the commodities concerned.

Inventory of institutional capacity

Based on the arguments presented, the authors got down to the task of designing a questionnaire on operating capacity (Appendix 1), which was then sent out to national institutions in Argentina and Brazil and the International Maize and Wheat Improvement Center (CIMMYT). A summary of the information collected is to be found later in the section entitled "Economic and Technological Frame of Reference."

Stages of the Analysis

For it to be implemented successfully, the model calls for the following sequence of stages to be completed:

Economic and technological frame of reference

In order to produce information on which to base a decision as to the desirability of conducting joint research into topics of common interest where the countries of the region allocate resources unilaterally, and to identify new potential areas of research, there is a need for information on the relative position of the countries of each region and the rest of the world in the context of (a) world trade, (b) projection of market trends, (c) world outlook vis-à-vis technology, (d) main production systems used in the regions, and (e) their constraints (possible demand for technology). Information of this kind provides an economic and technological frame of reference that can be used to underpin decisions as to which joint research should be included in the simulation runs.

Institutional frame of reference

This step consists of generating institutional information to complement the economic and technological data. The analysis calls for information concerning (a) characteristics of the national research systems of each country, (b) national research priorities, (c) inventory of human, physical, and economic resources available in the national systems and international centers involved in the commodities and areas of interest, (d) current research plans and the orientation of the research, and (e) areas of common interest. Like the economic and technological frame of reference, the purpose of this information is to identify lines of work that could be tackled jointly and used in the model runs, in order to optimize the cost-benefit ratio for countries in the region.

Model runs and analysis of results

Once the areas of current and potential common interest have been established, the model runs generate data that make it possible to evaluate the costs and benefits of separate research efforts, comparing them with those of joint research. For the last stage in the process, deciding where the joint research should be conducted, two aspects are analyzed: (a) economic indicators generated by the implementation of the PEAT model and (b) institutional capacity.

ECONOMIC AND TECHNOLOGICAL FRAME OF REFERENCE

The following is a brief analysis of world trade in wheat, based on a study of supply, demand, consumption patterns, and the world and regional technological outlook.

Wheat Production and the World Market

World wheat production has risen steadily. Disregarding weather-related, short-term fluctuations, production rose on average by roughly 3.5% a year between 1960 and 1980, and then fell back to an average of 2% per year during the 1980s (CIMMYT 1992).

Prior to the 1980s, this sustained growth was due to an increase in wheat acreage and yield increases. Over the past decade, however, the cultivated area has been falling by an average of 1% per year. Yields have been rising by 2-3% per year, continuing a 40-year trend and reflecting the increased use of improved germ plasm, fertilizers, and quality inputs.

Table 1 details wheat acreage, yields, and production by region over the three-year period 1989-91.

Table 1. Wheat: Cultivated area, yield, and production.

	Area (millions of ha)	Yield (t/ha)	Production (millions of t)
Sub-Saharan Africa	1	1.5	2
West and North Africa	27	1.7	45
South Asia	33	2.1	69
East Asia (China)	31	3.1	95
Latin America	10	2.1	21
Developing countries	102	2.3	233
Industrialized countries	125	2.7	332
World	228	2.5	565

Source: CIMMYT 1992.

The most important recent developments in the world market have been a decline in world production over the past year accompanied by a big upsurge in demand from the countries of the former Soviet Union. This has substantially reduced world stocks and pushed up prices. Demand from these countries is expected to be sustained and should account for roughly 20% of world trade over the next few years. Prices on the world market are expected to rise over the next few years and reach US$200 per ton by the year 2000 (World Bank 1992).

Trends in Supply and Projections of Demand

Wheat supplies over the long term appear to hinge basically on the negotiations between exporting countries aimed at cutting production subsidies in Europe and North America. On the demand side, the projected annual rate of growth for 1990-2005 suggests that consumption will rise by 2.1%. Table 2 shows the demand by region in 1990 and the projected demand for the year 2005.

Table 2. Wheat: Projections of demand.

	Demand (millions t) 1990	2005	Growth in demand 1990-2005 (% per year)
Sub-Saharan Africa	7	11	3.3
West and North Africa	70	109	3.0
Asia	193	303	3.1
Latin America	25	36	2.4
Developing countries	296	459	3.0
Industrialized countries	285	331	1.0
World	581	790	2.1

Source: CIMMYT 1992.

The figures suggest a clear and growing trend toward increased demand from the developing world. Available data on consumption trends in the developing world points to a global increase in demand for all cereals in the order of 3.5% per year. The outlook for wheat is especially good, with a projected annual rise in consumption of 4.8%, placing it ahead of corn (4.3%), rice (3.1%), and other cereals (1.5%).

The projected increase in wheat consumption over the medium term reflects a process of growing urbanization and dietary diversification. The increase in per capita income for some developing countries and projected sustained relative growth in the developing world over the next few years suggest that the trend toward higher wheat consumption will be maintained.

World Outlook for Technology

In the medium term, yield increases worldwide also seem to be contingent upon developments in the world's most important wheat-growing region: Eastern Europe and the former Soviet Union. At present, the impact on grain production of the economic-political reforms underway is not clear. Economic pressures are just as likely to cause production in that part of the world to rise as to fall. Improved varieties will very probably be adopted in Europe and the USA, and the prospects for yield increases are excellent. If the region is able to obtain credit and good prices, it will continue to be an important market for wheat over the medium term. If policies designed to stimulate the private sector and the adoption of new technology remain in place, the region could become an exporter over the long term.

The technological outlook worldwide suggests that there will be a marked increase in the adoption of the semidwarf varieties of wheat first developed by CIMMYT. These currently account for around 70% of the area under cultivation in developing countries, excluding China.

However, production in the developing countries will have to double over the next 20 years if it is to keep pace with domestic demand. This will call for more technology and better management to conserve natural resources.

Should there be further decisions along the lines of the one adopted by the Council of Ministers of the European Economic Community (May 1992), which cut price subsidies for wheat and replaced them with direct payments to farmers, rising prices will lead to an increase in wheat acreage outside Europe. Such an increase could bring about technological changes in many countries that are currently net importers of wheat in order to step up production. At the same time, it would benefit traditional wheat-exporting countries. Higher profit margins thanks to low production costs would stimulate increased production.

Binational Production and Trade, Argentina-Brazil

There are some clear differences between Argentina and Brazil as far as production and consumption patterns are concerned. However, in view of the fact that the two countries share a common border, and given their growing complementarity in trade and certain common characteristics as regards production and consumption, it is highly likely that they will develop closer trade links in the future. With the additional impetus provided by the Southern Cone Common Market (MERCOSUR), there would seem to be good prospects for achieving economies of scale in research and establishing common priorities, whereby it would be possible to coordinate actions and undertake joint ventures.

Wheat production in Argentina, a traditional producer, has remained steady in recent years at around 10 million tons, with yields of roughly 1900 kg/ha. Production in Brazil, on the other hand, has been subject to constant fluctuations over the past ten years. When production peaked at 6.2 million tons in 1987 thanks to favorable credit policies and price supports, the country almost became self-sufficient. However, since 1988 production has fallen steadily and currently stands at around three million tons (1991). Changes in economic policy implemented in 1988, including the privatization of marketing operations, seem to have triggered this fall (Días and Rodrigues 1993).

Table 3 provides data on the acreage, yields, and production of the two countries for the period 1989-91.

Consumption in Argentina accounts for slightly less than half of all production, leaving around 5.5 million tons a year for export. Sales to Brazil, which imported 3.2 millions from its neighbor in 1992, are growing.

Table 3. Wheat: Cultivated area, yield, and production in Argentina and Brazil (1989-91).

	Argentina	Brazil	Binational
Harvested area (thousands of ha)	5231	2692	7923
Yields (kg per ha)	1875	1429	1730
Production (thousands of t)	9820	3889	13709

Source: Días and Rodrigues 1992; Macagno and Gomez 1992.

Brazil, on the other hand, consumes nearly twice as much as it produces and imports increasingly large amounts of this cereal in order to meet domestic demand. Table 4 shows the production, consumption, and the marketable surplus of the two countries over the period 1989-91.

Table 4. Wheat: Production, consumption, and marketable surplus in Argentina and Brazil.

	Production (thous. t)	Consumption (thous. t)	Exports (thous. t)	Imports (thous. t)
Argentina	9820	4372	5448	0
Brazil	3889	7455	0	3566

Source: CONAB 1993; FIEL 1993.

In addition to the bilateral trade in grains, a recent trade agreement established quotas of exports of wheat flour of 200,000 and 300,000 tons for 1992 and 1993, respectively.

Current per capita wheat consumption is roughly 155 kg and 51 kg per year in Argentina and Brazil, respectively. According to some estimates, Brazil could be importing around 15 million tons a year by the year 2005 (Suplemento Clarín 1993). The current combined population is put at roughly 190,000,000, with an estimated annual growth rate of 1.1% for Argentina and 1.8% for Brazil until the year 2000.

Production Characteristics and Constraints in Argentina and Brazil

Divided among seven main wheat-producing areas, Argentinean wheat production is centered on the pampas region, with different prevailing agroecological characteristics. Most of Brazil's production is concentrated in the southern, central-southern, and central regions.

Argentina enjoys average yields of between 1500 kg/ha and 2400 kg/ha, and varieties that are more resistant to disease and the prevailing climatic conditions have helped push up yields by 1.5% per year. There are a variety of ways in which average productivity could be increased, with potential yields in some cases of over 5500 kg/ha (without the use of fertilizers). Double cropping, mainly rotating wheat and soybeans, is one of the most common systems and presently accounts for slightly over 40% of Argentina's current production.

As wheat is one of the country's most traditional crops, farmers generally react positively to technological change and adopt innovations provided that cost/benefit ratios make them viable. With farmers already accustomed to using improved varieties, the country has been able to overcome production constraints with relative success.

However, at present there are structural, technological, and economic constraints to yield increases for this crop. Many of these could be overcome with the help of the public/private research system.

A recent study (DNAP 1993) quantified the losses or economic costs to wheat production of existing constraints and put them at roughly US$350 million a year (32% of the value of total production). The main factors involved are harvest and postharvest losses, and low nutrient retention and soil degradation. Abiotic factors such as water stress and frosts are the second most important factors that will have to be dealt with if yield increases are to be obtained. Diseases, weeds, and pests are another important reason for lost production.

In the case of Brazil, certain climatic and technological constraints and structural problems characteristic of the different prevailing production systems make it impossible to achieve potential yields/ha of around 5000 kg/ha in some agroecological zones.

In short, the main technological constraints in the southern wheat-growing region include soil acidity and a phosphorus deficit, huge losses due to soil erosion in the south, combined with the high rate of root diseases that make it necessary to rotate crops in such a way as to be uneconomical. In the central-southern wheat-producing region, soil compaction causes roots to be concentrated on the surface and thus makes wheat susceptible to drought. Soils in the central region, on the other hand, have a low water retention capacity that makes them susceptible to erosion. Fertilization with phosphorus is necessary, but this is further complicated by a shortage of water and electricity for irrigation. Other harvest and postharvest problems and constraints, plus typical wheat diseases and pests, mean that Brazil faces similar risks to those experienced in Argentina.

RESULTS AND DISCUSSION

Results of the Inventory

Based on the methodology described, the team carried out an inventory of operating capacity, with the information broken down by human, physical, and economic resources. To this detailed information on the resources at the disposal of Brazil and Argentina's national research systems was added data from the CIMMYT, given the latter's importance as an international center working specifically with wheat.

In the case of Argentina, the inventory drew on data on INTA's human, physical, and economic resources, as this institution accounts for a very high percentage of direct research expenditure on wheat. In the case of Brazil, the data covers the public/private research sector, composed primarily of EMBRAPA (and its centers, CNPTrigo, CNPSoja, CPA Tierras Bajas and CPAO, ex-UEPAE Dourados), private cooperatives (cooperative wheat research centers, Fundación Centro de Estudios de Pesquisas [FUNDACEP] and the Organización Central de Cooperativas del Estado de Paraná [OCEPAR]), and state research institutes (Instituto Agronómico Campinas [IAC] and IAPAR). The institutions excluded from the inventory were the Empresas de Pesquisa Agropecuaria de Minas Gerais (EPAMIG), the Empresa Goiana de Pesquisa Agropecuaria (EMGOPA), and the universities, which play only a minor role in wheat research in Brazil.

The data on CIMMYT includes every resource at this center's disposal for fulfilling its worldwide mandate, without prorating expenditure in Argentina and Brazil. Tables 5 through 9 contain the baseline data on human resources and their level of training, researcher turnover, expenditure by subject matter area, and salaries for each of the three sources of data.

The inventory carried out made it possible to explore in greater depth the orientation of research by subject matter area, its probabilities of success, production constraints and their impact on yields, and so on.

Gleaning information from work programs, regional research projects were carried out in Brazil and data extracted from earlier studies of the prevailing production systems with the technology packages in use for wheat (Ambrosi *et al.* 1993; Días and Rodrigues 1993).

In Argentina, a recent study was updated with the results of the orientation of the research conducted under the INTA's wheat research program (Macagno *et al.* 1992), and the findings of a survey with a description of the different technological levels by wheat region were used (Cap *et al.* 1992).

Tables 10 and 11 contain data on the different technological levels and yields of the various wheat regions in both countries.

Table 5. Wheat: Availability of human resources by subject matter area (equivalent to person EP/July 1993.*

	Improvement (EP)	Plant protection (EP)	Management (EP)	Total (EP)
Argentina	13.1	6.9	9.1	29.1
Brazil	14.2	8.8	9.2	32.2
CIMMYT	20.0	9.0	5.0	34.0
ARG + BRA	27.3	15.7	18.3	61.3
ARG + BRA + CIMMYT	47.3	24.7	23.3	95.3

* Real availability; based on time devoted to each field of wheat research. Does not include staff away on postgraduate courses. In the case of CIMMYT, includes associate staff and two managers.

Source: Compiled by the authors from data supplied by INTA, EMBRAPA, and CIMMYT.

Table 6. Wheat: Distribution of human resources by level of training (in percentages–July 1993).

	%			
	B.Sc.	M.Sc.	Ph.D.	Total
Argentina	61	33	6	100
Brazil	6	64	30	100
CIMMYT	100	100		
ARG + BRA	32	49	19	100
ARG + BRA + CIMMYT	20	32	48	100

Source: Compiled by the authors from data supplied by INTA, EMBRAPA, and CIMMYT.

Table 7. Wheat: Researcher turnover 1991/92.

	1991		1992		Balance
	Incoming	Outgoing	Incoming	Outgoing	1991/92
Argentina	—	2	—	—	-2
Brazil	—	5	—	—	-5
CIMMYT	1	2	1	2	-2
ARG + BRA	—	7	—	—	-7
ARG + BRA + CIMMYT	1	9	1	2	-9

Source: Compiled by the authors from data supplied by INTA, EMBRAPA, and CIMMYT.

Table 8. Wheat: Annual expenditure by subject matter area (in thousands of US$).*

	Genetic improvement	Plant protection	Management	Total
Argentina	1,261.3	695.7	809.6	2,766.6
Brazil	1,518.7	660.3	526.3	2,705.3
CIMMYT**	7,480.0	3,390.0	1,113.0	11,983.0
ARG + BRA	2,780.0	1,356.0	1,335.9	5,471.9
ARG + BRA + CIMMYT	10,260.0	4,746.0	2,448.9	17,454.9

* Includes labor costs, operating expenses, and indirect costs.
** Includes special projects additional to the core budget worldwide.

Source: Compiled by the authors from data supplied by INTA, EMBRAPA, and CIMMYT.

Table 9. Wheat: Annual real salaries and net take-home pay (in thousands of US$ july 1993).

	B.Sc.		M.Sc.		Ph.D.		Mean	
	Real	Net	Real	Net	Real	Net	Real	Net
Argentina	19.5	29.2	27.3	40.9	35.1	52.6	27.3	40.9
Brazil	18.0	27.9	22.0	34.1	25.0	38.7	21.7	33.6
CIMMYT	—	—	—	—	48.7	75.0	48.7	75.0

Source: Compiled by the authors from data supplied by INTA, EMBRAPA, and CIMMYT.

Table 10. Argentina: yields by technological level.

Agroecological zone	Wheat region	Yield (t/ha) by technological level						
		Low	% Tot. Area	Average	% Tot. area	High	% Tot. area	Tot. area (ha)
Santa Fe I	II N	2.00	10.00	2.50	50.00	3.20	40.00	376 400
Santa Fe II	II N	1.50	5.00	2.20	40.00	3.00	55.00	78 000
Santa Fe III	I	1.20	10.00	1.90	65.00	2.50	25.00	313 000
Santa Fe IV	I	1.80	5.00	2.30	65.00	2.80	30.00	55 000
Buenos Aires I	II S	1.50	30.00	2.20	40.00	2.60	30.00	40 800
Buenos Aires II	II S	1.70	20.00	2.40	70.00	3.50	10.00	731 900
Buenos Aires III	IV	1.90	25-30	2.35	40-45	3.00	30.00	790 000
Buenos Aires IV	V S	1.00	90.00	1.50	10.00		0.00	300 000
Buenos Aires V	V S	1.40	50.00	1.90	40.00	2.50	10.00	950 000
Córdoba I	V N	1.80	18.00	2.20	65.00	2.60	17.00	225 000
Córdoba II	V N	1.00	25.00	2.00	60.00	3.00	15.00	89 500
Córdoba III	V N	1.20	27.00	1.80	64.00	2.20	9.00	180 000
La Pampa I	V S	1.70	20.00	2.40	70.00	3.50	10.00	171 600
La Pampa II	V S	1.40	50.00	1.90	40.00	2.50	10.00	128 600
Entre Ríos	III	1.35	20.00	2.00	40.00	2.80	40.00	82 500
Chaco y Formosa	NEA	1.20	11.00	1.70	79.00	2.50	10.00	15 000
AVERAGE		1.48	—	2.08	—	2.81	—	—
Total								4 527 300

Source: Cap *et al.* 1992.

Table 11. Brazil: Yields by technological level.

Agroecological zone	Yield (t/ha) by technological level						
	Low	% tot. area	Average	% tot. area	High	% tot. area	Tot. area (ha)
CNPT1	0.90	50.00	1.14	30.00	1.40	20.00	277,400
CNPT2	1.20	50.00	1.60	30.00	2.20	20.00	760,550
CNPT3	1.90	50.00	2.30	30.00	2.70	20.00	586,000
CNPT4	0.90	60.00	1.60	25.00	1.80	15.00	544,720
CNPT5	1.20	40.00	1.60	35.00	2.10	25.00	1,011,630
Average	1.22		1.65		2.04		
Total							3,180,300

Source: Ambrosi *et al.* 1993.

Brazil has a NARS made up of provincial institutes, private enterprises engaged in generation and transfer activities, universities, and other organizations. EMBRAPA is responsible for coordinating the NARS via some 40 national and regional research centers. EMBRAPA's wheat program is a key component of the wheat research system and executes a large proportion of the activities at the Passo Fundo Centro Nacional de Investigación en Trigo (Passo Fundo National Wheat Research Center) in Rio Grande do Sul State.

Other important stakeholders in the national wheat research program are the National Soybean Research Center in Londrina (Paraná) and the Temperate Lowland Agricultural Research Center in Pelotas (Rio Grande do Sul). Cooperatives such as OCEPAR and FUNDACEP and provincial institutes such as IAPAR, IAC, EMGOPA, and EPAMIG are also part of the program, and their work is carried out via plans and projects that are linked directly or indirectly to the wheat program.

In Argentina, the country's most important wheat research is channeled through the INTA. However, more than six private nurseries execute actions related to genetic improvement and play an important role in the total amount of wheat produced through varieties that they have developed. Universities participate in the technology generation system, though through actions indirectly linked to the INTA's wheat program. There are integrated projects and increasing efforts to avoid duplication.

The INTA's work is carried out through the National Cereal and Seed Program, Wheat Subprogram, based at the Cordoba Regional Center's Marcos Juarez research station. The Pergamino and Balcarce, Paraná, Bordenave, Anguil, Manfredi, H. Ascasubi, Rafaela, Barrow, and other research stations take part in genetic improvement, plant protection, and crop management plans and projects. INTA's Castelar Research Center is a key component for basic and applied research, executing activities in cooperation with the National Research Program (PAN) for cereals and seeds and the Wheat Subprogram.

INTA's Wheat Program is one of the institution's longest running activities. It has highly trained personnel with extensive experience and numerous research achievements, having produced varieties that have been widely adopted and developed cultivation systems.

For the purposes of analysis, Argentina was divided into 16 wheat-producing zones, as shown in Table 10. Each zone was subdivided into three technological levels: low, average, and high, with two columns for each level–average yields and the percentage of total cultivated area accounted for by each level in each zone.[8] By way of illustration, some 50% of farmers in the Santa Fe I Region belong to the average level (ATL), obtaining average yields of 2.5 t/ha. There are few farmers in the lowest category (10% of the total), while the remaining 40% pertain to the highest group, with 3.2 t/ha.

In Brazil,[9] production was divided into five wheat-producing zones, which are included in Table 11. Zone V (Mato Grosso) is potentially the biggest producer and has the largest cultivated area, while the system of irrigated wheat is the one best suited to the region. In contrast to the situation observed in Argentina, most farmers belong to the low (LTL) and average (ATL) levels.

Areas of Common Interest

Based on the identification of work plans and projects that revealed the current orientation of research in each country, work was carried out that aimed to achieve two objectives. The first involved the question of national priorities and the importance of each issue, and called for the identification of current production constraints and their economic impact. These problems were selected along with the possible actions that could be taken to resolve them or lessen their impact, and the costs associated with them. The second objective was to identify binational objectives and coordination mechanisms that would make it possible to tackle these problems by pooling resources.

Table 12 shows those subject matter areas in which the size of the problem or the constraint was similar. The second column deals with the geographic area where the problem occurs, while the following columns give data on the frequency of the occurrence

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8 In order to obtain data, groups of qualified informants were interviewed through the INTA's Strategic Planning Directorate. The interviewees included coordinators of INTA's national and regional research plans and the institution's researchers and extensionists. Qualified informants from other institutions (provincial governments, universities, etc.) and the private sector also took part. Based on a previously distributed form/guidelines, and with the consensus of the participants, the information was compiled by region and item.

9 Interviews were held with experts from EMBRAPA's research centers, state research institutes, universities, and research centers run by wheat cooperatives (FUNDACEP and OCEPAR).

of the problem and the size of the negative impact on yields. The "end product" column quantifies the expected effect of the research, based on the probabilities of success, the year in which the technology would become available, and the national and binational costs.

Areas of common interest were identified using the following criteria:

1. Identification of lines of research that are being carried out in the two countries simultaneously.

2. Of the group chosen in criteria 1, a subgroup of technologies was identified that could be transferable (adoptable) for both countries in the case of joint research.

The work programs of each country include technical details for each area of research. Only the main topic headings are mentioned in this paper.

Both countries are engaged in **leaf rust** research, and the results could be transferable were joint research to be carried out. According to Table 12, the technology would impact six regions in Argentina and three in Brazil, with an 80% probability of success, and the technology becoming available in 1998. Crop damage occurs every year in the Argentine regions IIN, I, IIS and III. In regions IV and VN, it occurs three times every ten years. In Brazil, damage occurs in five out of every ten years. The damage caused by leaf rust without technology is put at 5%-9%. With technology (end product), losses would be reduced to between 2.5% and 4.5%.

The **green aphid** impacts the VS region of Argentina and regions CNPT1, CNPT2 and CNPT3 in Brazil in three out of every ten years. With the appropriate technology, losses would be cut from 1% to 0.5% in Argentina, and from 3% to 2% in Brazil. There is an 80% probability of success for both countries.

Frosts cause damage in both countries once or twice every ten years. The adverse effects are considerable (between 40% and 60%), and it is estimated that the new technology that could be generated would cut these losses by half. The probabilities of success are rated at 50%-60%.

After analyzing the work programs for the development of new varieties for **border areas**, the team estimated that yields could be increased by 8% through the two countries' genetic improvement program. In Argentina, zone I (NEA) would be the one to benefit, and in Brazil zones 1, 2, and 3. The benefits would begin to accrue as of 1998, with an 80% probability of success.

The annual binational costs for the two countries are estimated to be in the region of US$1 million. It is worth pointing out that the economic indicators (internal rate of return, net present value, benefit/cost ratio) generated by the model runs reflect the total cost of

Table 12. Argentina-Brazil: Identification of common areas of interest in wheat research.

Subject matter area	Geographic area	Frequency of occurrence	Current negative impact on yields %	End product %	Probability of success	Year available	Cost US$ Direct	Cost US$ Labor	Binational cost US$
Leaf Rust Argentina	IIN	10 in 10	9	4.5					
	I, IIS, III	10 in 10	6	3	0.8	1998	41,113	217,8 45	
	IV, y VN	3 in 10	5	2.5					341,278
Leaf Rust Brazil	CNPT1 CNPT2 CNPT3	5 in 10	6 to 7	4.3	0.8	1998	16,254	66,066	
Green aphid 1/ Argentina	VS	3 in 10	1	0.5	0.8	1998	1,600	8,778	116,751
Green aphid 2/ Brazil	CNPT1 CNPT2 CNPT3	3 in 10	3	2	0.8	1995	11,591	94,782	
Frosts Argentina	VS, IV	2 in 10	60	30	0.6	2000	11,550	61,200	
	IIN, IIS	1 in 10	40	20					93,550
Frosts Brazil	All	2 in 10	45	22	0.5	2000	6,400	14,400	
Development of improved varieties 3/, Argentina	I (NEA)	10 in 10	8	0	0.8	2000	7,000	37,092	217,052
Development of improved varieties 4/, Brazil	South of Brazil	10 in 10	8	0	0.8	1998	28,000	144,960	
Total									939,098

1 Genetic improvement work program.
2 Biological control work program.
3 Similar agroecological zones.
4 Has a bigger impact on the final price, roughly an additional 2.5%.

Source: Compiled by the authors from data supplied by EMBRAPA and INTA.

technology generation but not of transfer, which was omitted from the model because no data was available for Brazil, where the private sector plays a key role in extension activities. However, given that extension is location-specific and therefore cannot be consolidated into joint activities by the two countries, the omission of these resources would increase the internal rates of return (IRRs) of the national and consolidated scenarios, maintaining the relationship between consolidated and nonconsolidated rates.

Other Data Used in the PEAT Simulation Runs

Rates of mobility between levels

In order to apply the PEAT model, the rate of mobility between levels has been defined as the percentage of hectares that move up to the next technological level each year, based on increased productivity. Tables 13 and 14 show the rate of mobility between levels for Argentina and Brazil, respectively.

Table 13. Argentina: Rate of mobility between levels.

Agroecological zone	Mobility between technological levels (annual rate)	
	Low to average	Average to high
Santa Fe I	2.00	10.00
Santa.Fe II	2.00	5.00
Santa Fe III	2.00	4.00
Santa Fe IV	2.00	5.00
Buenos Aires I	10.00	5.00
Buenos Aires II	10.00	5.00
Buenos Aires III	3.00	5.00
Buenos Aires IV	3.00	5.00
Buenos Aires V	3.00	5.00
Córdoba I	1.40	0.80
Córdoba II	1.40	0.80
Córdoba III	1.40	0.80
La Pampa I	10.00	5.00
La Pampa II	3.00	5.00
Entre Ríos	1.00	0.50
Chaco-Formosa	2.00	2.00

Source: Compiled by the authors from data supplied by INTA.

Table 14. Brazil: Rate of mobility between levels.

Agroecological zone	Mobility between technological levels (annual rate)	
	Low to average	Average to high
CNPT1	2.50	2.00
CNPT2	2.50	2.00
CNPT3	2.50	2.00
CNPT4	2.50	2.00
CNPT5	2.50	2.00

Source: Compiled by the authors from data supplied by EMBRAPA's National Wheat Research Center.

Parameters of the logistical function of adoption

Mean adoption time (ø)

Defined as the time in years between t_d (availability of technology) and $t_{0.5}$ (50% of farmers adopt the practice). In order to be able to use it in the PEAT model, the definition was modified, with $t_{0.5}$ being the moment when 50% of the area under cultivation uses the new technology. Based on empirical data concerning the adoption of improved varieties of barley in Mexico (Byerlee and Hesse 1982) and consultations with qualified informants, the team decided to adopt the following values for Argentina and Brazil:

Technological level	Mean adoption time (ø)
High	2
Average	3
Low	4

Adoption ceiling (K)

Standardized as 1 (one). Sensitivity tests showed a 1% variation in the IRRs for each 10% adjustment in *K*.

Coefficient of adoption constraints (α)

In the absence of empirical data for Brazil, the team decided to adopt the value α=1 (neutral) for the simulations.

Note: This work highlighted the importance of having empirical data on the dynamics of adoption, broken down by agroecological region, commodity, and technological level, in order to substantially enhance the accuracy of the estimates of benefits.

Elasticity of supply (δ)

Based on recent work done by Macagno and Gomez (1992), and following consultations with qualified informants, the following values were assigned for both countries.

Technological level	Elasticity
High	1.0
Average	0.9
Low	0.8

Calculation of costs and benefits

Five scenarios were simulated:

- **EP:** scale by country (x 2)
- **EBS:** binational scale, without consolidation.
- **EBC:** joint binational scale, with consolidation (x 2).

Benefits

- **EP:** The available data was used to simulate the benefit flow for each country separately. The only adjustment was to put back by one year the date of the availability (t_d) of the technology estimated by the researchers consulted.

- **EBS:** The benefits were calculated by adding together the values estimated for EP.

- **EBC:** This is the same as EBS plus the resources saved in a country, making it possible to transfer personnel abroad. These resources are made up of the direct costs (EP level) plus 50% of labor costs in the country where they were released. The value of t_d estimated in EP was maintained, though it would be reasonable to expect the technology to be available sooner as a result of the intensified efforts.

Costs

Labor

- **EP:** The available data based on the inventory of institutional capacity was used, increased by 50% (so as to reflect medical insurance, pension contributions, etc.).

- **EBS:** The labor costs of the two countries were added together (adjusted in the same way as EP).

- **EBC:** The labor costs of the country where the consolidation would be located were used, plus 50% of the labor costs of the counterpart country. To simulate the consolidation for Argentina, the wage bill for the personnel transferred from Brazil was increased 60% to reflect the difference in purchasing power. The wage bill for "international" staff was also increased 20% for the first and fourth years (to cover initial expenses, with a four-year turnover).

Direct costs

- **EP:** The information provided in the reports prepared for this purpose was used, without modification.

- **EBS:** The values for EP Brazil and EP Argentina were added together.

- **EBC:** The EP values were increased 33% (in the country which would be the site of the consolidation) to cover the additional expenses generated by the increase in research activities as a result of the incorporation of the personnel transferred by the counterpart.

Adjustment

The values of the total annual cost were multiplied in every case by a factor of three so as to take into account the following:

— The impact of the indirect costs (administrative staff, library, laboratory, and studios) and overheads.

— The cost of the research already carried out, for the period t_0 - $t_{(0-x)}$, where x represents the year of the actual start of the work.

Results of the Simulations[10]

The following results were obtained from model runs for each of the scenarios described in the calculation of costs and benefits:

a. IRR (internal rate of return)
b. NPV (net present value)
c. Benefit/cost (B/C)

For the EBC scenarios, the NPV of the resources released (direct + staff) in the country transferring the researchers was also calculated. Table 15 provides a summary of the 20 simulations (4 topics x 5 scenarios).

IRR sensitivity analysis

The sensitivity of the IRRs was analyzed with respect to the following:

a. Variations in benefits and/or costs.[11] The results are summarized in Table 16.

b. Variations in the F.O.B. price (± 20%). The results are summarized in Table 17.

Discussion of the results

Project to reduce damage caused by leaf rust

The difference between the IRR/EBC for Argentina (48.87%) and Brazil (62.09%) clearly favors the latter country as the site of the consolidation. This conclusion is reinforced by the relative amount of resources released (US$604,842/US$157,368).

Reduction of damage caused by the green aphid

The difference in IRR/EBC values suggests that the research should be consolidated in Argentina (43.51%/35.25%). The resources released confirms this initial impression (US$103,723/US$24,134).

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10 A discount rate of 12% was applied.

11 The purpose of the value corresponding to the increase in costs without variation in benefits is to estimate the impact of the overestimation of benefits due to the noninclusion of the component associated with transfer and/or extension.

Table 15. Simulation runs: Summary of results.

	1	2	3	4	5
Reduction in damage caused by leaf rust					
	1	2	3	4	5
IRR	50.29%	37.63%	47.77%	48.87%	**62.09%**
NPV	28 417 368	4 374 884	32 792 252	33 047 123	34 924 963
B/C	9.89	5.31	8.79	9.00	14.54
Resources released (NPV)			Direct costs	66 827	169 032
in Brazil (a) and Argentina (b)			Labor costs	90 541	435 810
			Total released	157 368 (a)	**604 842** (b)
Reduction in damage caused by green aphid					
	1	2	3	4	5
IRR	30.69%	34.71%	34.15%	**43.51%**	35.26%
NPV	323 605	1 954 015	2 277 621	2 609 114	2 346 700
B/C	3.53	3.55	3.55	4.76	3.79
Resources released (NPV)			Direct costs	27 840	6 578
in Brazil (a) and Argentina (b)			Labor costs	75 883	17 556
			Total released	**103 723** (a)	24 134 (b)
Reduction in damage caused by frosts					
	1	2	3	4	5
IRR	87.73%	46.80%	83.23%	84.64%	**97.57%**
NPV	118 605 141	3 136 808	121 741 949	121 854 432	122 461 482
B/C	110.4	11.12	88.32	92.08	147.76
Resources released (NPV)			Direct costs	31 793	57 376
in Brazil (a) and Argentina (b)			Labor costs	23 845	163 200
			Total released	55 638 (a)	**220 576** (b)
Development of improved varieties for subtropical conditions					
	1	2	3	4	5
IRR	5.19%	48.14%	44.15%	**51.9%**	45.73%
NPV	221 164	17 923 369	17 702 206	18 575 565	17 931 784
B/C	0.59	9.4	7.61	9.62	8.06
Resources released (NPV)			Direct costs	115 119	28 780
in Brazil (a) and Argentina (b)			Labor costs	198 663	74 184
			Total released	**313 783** (a)	102 964 (b)

1: Scale (Argentina).
2: Scale (Brazil).
3: Binational scale, without consolidation.
4: Binational scale, with consolidation (Argentina).
5: Binational scale, with consolidation (Brazil).

Source: Compiled by the authors.

Table 16. IRR: Sensitivity analysis with regard to costs and benefits (%).

Reduction of damage caused by leaf rust					
	1	2	3	4	5
+25% BENEF. & -25% COSTS	61.06	46.97	58.26	58.60	69.13
+10% BENEF. & -10% COSTS	54.41	41.21	51.78	52.12	62.12
-10% BENEF. & + 10% COSTS	46.32	34.18	43.89	44.23	53.59
-25% BENEF. & + 25% COSTS	40.44	29.05	38.16	38.50	47.39
-25% FIXED BENEF. & COSTS	44.64	32.71	42.25	42.59	51.81
+25% FIXED COSTS & BENEF.	45.88	33.80	43.47	43.81	53.13
Reduction of damage caused by green aphid					
	1	2	3	4	5
+25% BENEF. & -25% COSTS	39.39	46.87	45.89	52.14	46.66
+10% BENEF. & -10% COSTS	34.02	39.23	38.53	44.33	39.34
-10% BENEF. & + 10% COSTS	27.46	30.48	30.05	35.35	30.91
-25% BENEF. & + 25% COSTS	22.67	24.47	24.20	29.16	25.09
-25% FIXED BENEF. & COSTS	26.09	28.73	28.36	33.55	29.22
+25% FIXED COSTS & BENEF.	27.10	30.02	29.61	34.88	30.47
Reduction in damage caused by frosts					
	1	2	3	4	5
+25% BENEF. & -25% COSTS	98.63	55.36	93.84	94.42	104.39
+10% BENEF. & -10% COSTS	91.93	50.11	87.32	87.89	97.51
-10% BENEF. & + 10% COSTS	83.63	43.57	79.23	79.80	88.99
-25% BENEF. & + 25% COSTS	77.48	38.71	73.24	73.80	82.68
-25% FIXED BENEF. & COSTS	81.88	42.19	77.53	78.09	87.20
+25% FIXED COSTS & BENEF.	83.18	43.21	78.79	79.35	88.53
Development of improved varieties for subtropical conditions					
	1	2	3	4	5
+25% BENEF. & -25% COSTS	11.85	58.43	54.07	58.56	55.12
+10% BENEF. & -10% COSTS	7.74	52.07	47.94	52.24	48.95
-10% BENEF. & + 10% COSTS	2.70	44.33	40.47	44.54	41.44
-25% BENEF. & + 25% COSTS	-0.99	38.70	35.04	38.93	35.96
-25% FIXED BENEF. & COSTS	1.65	42.72	38.92	42.93	39.87
+25% FIXED COSTS & BENEF.	2.43	43.92	40.07	44.12	41.03

1: Scale (Argentina).
2: Scale (Brazil).
3: Binational scale, without consolidation.
4: Binational scale, with consolidation (Argentina).
5: Binational scale, with consolidation (Brazil).

Source: Compiled by the authors.

Table 17. NPV: Analysis of sensibility to the F.O.B. price (%).

Project	Price (US$/t) 80	100*	120
Improved varieties for subtropical conditions			
Scale (Argentina)	2.07	5.19	8.07
Scale (Brazil)	42.36	48.14	53.42
Binational scale, without consolidation	38.61	44.15	49.21
Binational scale, with consolidation (Argentina)	45.19	51.39	52.36
Binational scale, with consolidation (Brazil)	57.96	45.73	66.01
Reduction in damage caused by frosts			
Scale (Argentina)	85.76	87.73	89.55
Scale (Brazil)	41.86	46.80	51.22
Binational scale, without consolidation	81.18	83.23	85.13
Binational scale, with consolidation (Argentina)	82.58	84.64	86.56
Binational scale, with consolidation (Brazil)	95.36	97.57	99.63
Reduction in damage caused by leaf rust			
Scale (Argentina)	46.87	50.29	53.54
Scale (Brazil)	32.45	37.63	42.37
Binational scale, without consolidation	44.12	47.77	51.23
Binational scale, with consolidation (Argentina)	45.19	48.87	52.36
Binational scale, with consolidation (Brazil)	57.96	62.09	57.96
Reduction in damage caused by green aphid			
Scale (Argentina)	26.97	30.69	34.23
Scale (Brazil)	28.50	34.71	40.68
Binational scale, without consolidation	28.27	34.15	39.82
Binational scale, with consolidation (Argentina)	36.84	43.51	49.97
Binational scale, with consolidation (Brazil)	29.38	35.26	40.13

* Price used in the simulation runs.

Source: Compiled by the authors.

Reduction of damage caused by frosts

The benefits of this technology are more favorable if the research is conducted in Brazil rather than in Argentina, given that the IRR/EBC is higher in Brazil (97.57%) than in Argentina (84.64%). In addition, more resources are released if the research is consolidated in Brazil rather than in Argentina: in Argentina, US$220,578 are saved. On the other hand, in Brazil the savings total only US$55,638.

Development of improved varieties suited to subtropical climates

The IRRs/EP for previous projects were higher than the discount rate. In this case, the IRR/EP for Argentina is 5.19%, with an NPV of -US$221,164. For Brazil, on the other hand, the IRR/EP is 48.14%.

On the national scale, the result for the Argentine project means that the social returns are negative. However, at the EBC level the best option is the consolidation of the research work in Argentina (IRR/EBC Argentina: 51.39%; IRR/EBC Brazil: 45.73%). More resources are also released if the project is carried out in Argentina (US$313,783/US$102,964). However, this result does not mean that the EBC/Argentina option is viable, as for consolidation to be worthwhile an IRR/EP > discount rate is needed, which is not the case in this example. Compensation from the counterpart is needed for partnerships to be considered in Argentina. These criteria are discussed in more detail in the next section.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It is clear from the results of the binational exercise that, given the receptiveness of regional decisionmakers to new ideas (as evidenced by the existence of the IICA/IDB Agreement), there is a range of possibilities as far as the role and functioning of the different actors working in the LAC technology generation and transfer system (TGT) are concerned.

For the past three decades, the members of the system have basically operated as monopolistic suppliers of agricultural technologies, especially those regarded as being public goods (no users can be excluded). This has led to the intranational and/or transnational coexistence of research centers, programs, and projects with a good deal of redundancy and, therefore, low levels of national/regional efficiency. The processes underway worldwide, particularly market reforms and the restructuring and redefining of the role of the State, have brought about an abrupt change in the way in which societies perceive organizations funded out of the public purse.

While restrained by comparison with the criticism of other public sector agents, the questioning of the role the NARIs and other stakeholders in the system is clearly visible. This means that the system still has room for maneuver in undertaking initiatives and neutralizing threats.

The most radical change would be the incorporation of these suppliers of public goods and a system of institutional competitiveness, which could be defined as their ability to maintain and possibly even increase their share of the public resources allocated for the function that they perform. The idea would be that society will note the increased efficiency of these institutions in their use of public funds, and reward the most efficient with a bigger allocation (equivalent to a bigger market share).

The proposals detailed in the following section are designed to attain the objective described in the preceding paragraph and would be more likely to prompt important institutional changes if the technology generation and transfer units (TGTUs) were, to be begin with, to compete for the resources that originate outside the system (e.g., those drawn from funds administered by funding and/or donor agencies such as the IDB, World Bank, etc.). Once the mechanisms are in place and their potential benefits become clear, there could then be a second stage that would include the resources of the LAC TGT system itself. This strategy would encourage a gradual rather than a traumatic process of trade creation between the suppliers of public goods.

Proposed Mechanism for Allocating IDB and/or Other Donor Resources

One or more areas of research regarded as having a high regional (or subregional) priority are identified. This identification can be done using "what if?" simulation runs of the PEAT model or some other method (TAC-LAC), based exclusively on the demand for technology.

Based on this data, and assuming the existence of extra-NARI resources that could be channeled into the TGT process, there are two decisions to be made:

1. To which projects should the external contribution be allocated?

2. To which TGTU from which national or international system should the external resources be allocated?

The sequence of steps to be followed in this case could be the following:

1. Identify the TGTUs with the operating capacity for executing the project (or which are already implementing lines of work in the same areas). This could be done drawing on the data contained in the inventory of institutional capacity.

2. If there are TGTUs with the necessary operating capacity, each will be invited to take part in a competitive bidding process. The invitation will be accompanied by as detailed a description as possible of the end-product anticipated (e.g., healthier peanut crops).

3. A closing date for proposals will be set.

4. The TGTUs taking part in the competitive bidding process (which could be NARIs, NARI research centers, NARI or mixed consortia, universities, foundations, CG centers, or private enterprises) will be required to provide the following information:

   — Description of the state of the art at the end of the project. In other words, exact details of the end product of the research effort (e.g., percentage of yield increases, lower costs, or improvement in quality), identifying the area of impact in the country where the TGTU is located, and estimating their transnational extrapolation.

   — Year in which the technology would be available.

   — Probabilities of success (this should include a list of the premises that must be met in order to attain the objectives described).

   — Annual costs (direct, indirect, and wage bill).

5. The Regional Priority-Setting Council's Decision-making Support System (SAD) would evaluate the IRRs of the different proposals[12] using the PEAT. The information concerning the quality of the TGTU could be used as a coefficient of adjustment of the probabilities of success (see recommendation b).

6. The project inflow component would be adjusted using weighted values of the national/regional impact. It is worth pointing out that if the proposal with the highest IRR is from a TGTU funded out of national resources and the impact on the country's agricultural production represents a sizable proportion of the total benefit, this could be adversely affected by a rate of correction that will reflect the asymmetry. (The same adjustment, this time upwards, could be made in those cases where the national/regional impact ratio is quite low and reflects a high degree of "altruism.") See the proposed decision-making criteria set out in this chapter.

7. If more than one TGTU offers conditions that reflect similar rates of return, the resources could be shared out among the successful bidders (after making an adjustment for the fixed costs) or the efforts consolidated in one of the research centers, after identifying the best strategy via PEAT simulations.

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12 Prior to this, the technical documentation would be evaluated by leading specialists not linked to the group making the offer in order to determine its feasibility.

8. If no TGTU in the region has operating capacity, institutions from outside the region would be invited to take part, provided that the technologies involved had a low degree of agroecological specificity. The procedure would be the same as the one followed at the regional level.

9. Should it prove necessary to install operating capacity in the region, the sequence of the stages of the analysis would be similar to those already described, factoring in the installation costs.

10. (h) and (i) can also be contrasted, adjusting the IRRs via coefficients that reflect the importance assigned to the region's autonomous capacity in the specific subject matter area.

Sample result

First level:

Three priority research areas (high ***Es*** with different β^p simulated using the PEAT): *A*, *B*, and *C*.

Second level:

- Implementation benefits and costs of specific projects in priority areas.
- IRRS of the preselected proposals.
- Description of the "state of the art" of the preselected proposals.

Proposed Decision-making Criteria for Resource Allocation Based on PEAT Model Runs

Case 1: national/local *IRR* < discount rate (= = > negative *NPV*).

A project generating results such as these would be a case of a "non"-economy of scale. Two alternative recommendations are proposed at the national decision-making levels:

1. Cancel the project (or reject the request for funds if it has not reached the execution stage).

2. Contract out its implementation to another TGTU outside the system[13] with high quality OC (provincial, national, international, or other). Under this option, the optimum

13 Competitive bidding generated by a national system.

level of compensation for the other unit in exchange for the execution of the project is important. The solution is to run the PEAT with lower and lower outflow values (starting from those included in the original proposal), until:

IRR = *DR* (discount rate) (= = > *NPV* = 0).

At this level, the project is neutral as far as the social returns are concerned. The outflow that results in the preceding equality represents the maximum amount that the system of which the TGTU is a member is ready to pay (based exclusively on economic criteria).

Case 2: national *IRR* > *DR* (= *NPV* > 0).

If the results are similar to these for all the participants on a multinational scale, two alternatives should be considered:

1. If the resources originate from within the system itself (as in the case of the INTA/EMBRAPA exercise):

   a) Run the PEAT, factoring in the regional costs and benefits.

   b) Run the PEAT after simulating the consolidation of efforts in each of the candidates.

The criteria for deciding where to implement the consolidation would be based on the following:

   a) The consolidated *IRR*/aggregate *IRR* ratio for each country.

   b) The resources released in each case in each TGTU/NARI.

As an incentive for the TGTU benefitting from the consolidation, a percentage of the resources to be released among the counterparts should be transferred to it.

2. If the resources originate from outside the system:

   The competitive bidding process should consider:

   - TIR/TGTU^{A} ($A + B + C$)[14]
   - TIR/TGTU^{A} ($B + C$)[15]
   - TIR/TGTU^{A} (A)[16]

14 IRR calculating the inflow for the entire area of impact.

15 *B* + *C* represents the transnational area impacted (benefitted) by the results of the technology generated by the TGTU^{A}.

16 A represents the benefits anticipated in the service area (associated with its financing schedule) of the TGTU whose offer is still under evaluation.

If a typical case of spillover: the score for center *A* would be adjusted downwards.

If a case of "spillunder": the score of the TGTU^A is revised downwards.

Recommendations

1. In the case of the INTA-EMBRAPA binational exercise, some of the results obtained from the simulations need to be analyzed in greater detail (especially the question of the amount of resources released), considering the consolidation alternative that offers the greatest social returns. The NPV of these resources for each project is the following:

   Rust..................US$604,842
   Green aphid......US$103,723
   Frosts................US$220,573
   Improvement.....US$313,183

   TOTAL ....US$**1,242,294**

   The NPV of the combined total costs/EP is.........US$**9,165,950**

   This means that the savings that could be achieved by consolidating ongoing technology generation activities in the two countries are of the order of **13.5%**. The total costs of the LAC NARIs plus the international centers belonging to the CG have been put at over US$600 million. If the extrapolation of the methodology developed for the Southern Cone into the rest of the region is valid, savings of US$81 million could be achieved.

   If these indicators are correct, a regional priority-setting system composed of a board and a team of experts that costs US$1 million a year to run, that produces its results after five years of work, and generates savings of US$81 million from the sixth year onwards, would produce results at a benefit/cost ratio of 11.38% and with an IRR of 113%. It should be borne in mind that the estimated impact is associated with the optimization of the allocation of resources already in use. The prospects for considerably enhancing the rate of return of the regional priority-setting system are good, bearing in mind the impact of competitive bidding mechanisms, which would lower the fixed costs of the institutional innovation.

   For all these reasons, the authors of this report are of the opinion that there is sufficient data to recommend the creation of the Regional Priority-Setting System.

2. The data contained in the inventory of institutional capacity is a valuable contribution to the optimization of resource allocation, but is lacking in one respect: the quality of the TGTU, given the fact that the information was supplied by the interested parties themselves. In other words, a strategic decision may be taken not to reveal some of

the stock of "private information." One way of making this private information public would be to establish an accreditation system for all TGTUs that wish to participate in the regional system. This mechanism, which would have to be designed by consultants hired especially for this purpose, would be loosely based on the one used by U.S. universities, incorporating elements used in the banking sector to evaluate credit worthiness. The end product would be an *ordinal* and a *cardinal* rating.

For example, with regard to plant protection for tropical crops, on the supply side we have the following:

$TGTU^x$: AA (first level)
$TGTU^y$: AB (intermediate level)
$TGTU^z$: CC (last level)

Thus, the ranking would be *X*, *Y*, and *Z* in that order, and there would also be a clear indication of the gap between the participants in the system. Operationally, the accreditation indicators could be incorporated into the competitive bidding process, fixing a "cut-off" point for the acceptance of offers, which would substantially reduce the transaction costs.

3. In the authors' opinion, the features that make the SAD attractive are the following:

— The fact that it is software-intensive. The SAD group should be small in number and composed of highly trained staff with proven experience in the area concerned.

— The (visible or hidden) operating capacity in the national systems and international centers should be supported and harnessed.

— It must be capable of generating interest in participating in the regional priority-setting system, ensuring that the methodological proposals and recommendations are incentive-compatible.

— Its terms of reference (function and objectives) should include the mandate of producing broad-based, permanent international opening: the FAO, international centers, universities, the European Economic Community, the U.S. Department of Agriculture, and so on.

— The SAD's technical secretary should act as the secretary general of the Regional Council (in a nonvoting capacity, along the lines of the UN Secretary General). This close working relationship with the voting members of the council would ensure that he/she enjoys enough support to be able to operate within and outside the region with a measure of credibility and responsibility not normally associated with technical secretaries. Officials of this kind are usually perceived by outsiders as being "recording secretaries," without powers to promote initiatives and much less undertake fruitful negotiations with institutions outside the system.

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