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Resource Allocation to Agricultural Research

Proceedings of a Workshop held in Singapore 8-10 June 1981

Editors: Douglas Daniels and Barry Nestel

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Cosponsored by:
International Federation for Agricultural Research and Development
International Development Research Centre

The untimely death of Dr J.D. Drilon, who was to attend the workshop as a representative of IFARD, is a great loss to all concerned with improving the welfare of the rural poor. This publication is dedicated to his memory.

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Research Priorities and Resource Allocation in Agriculture: The Case of Colombia

Fernando Chaparro, Gabriel Montes, Ricardo Torres, Alvaro Balcázar, and Hernán Jaramillo[1]

The purpose of this paper is to analyze the present experience of formulating a National Plan for Agricultural Research in Colombia. Emphasis is placed not on the substantive content of the plan (i.e., objectives, strategy, and proposed research programs) but on the methodological aspects involved in its formulation. Special attention is given to the criteria and methodological framework that are being used in the process of identifying technological requirements and research priorities (both in terms of agricultural products and research topics or issues) as instruments of resource allocation in this sector.

The first section of the paper provides general information on the present situation and orientation of agricultural research activities in Colombia. The objective is to give a very broad characterization of the present research effort within the country in terms of the areas it covers and the financial and human resources dedicated to it.

The second section analyzes the general methodological framework for the identification of research priorities that is presently being used in the formulation of the National Plan for Agricultural Research in Colombia. The approach that is being used is characterized by two phases: (1) identification of socioeconomic priorities in terms of products or problem areas and (2) determination of technological requirements and research needs for selected products or problem areas.

The Colombian experience with respect to the implementation of these two phases is analyzed in the last two sections of the paper. The institution that has been responsible for the formulation of this research plan in Colombia has been the Instituto Colombiano Agropecuario (ICA), with active collaboration from COLCIENCIAS (Colombian Fund for Scientific and Technological Research) and the National Planning Agency (D.N.P.). The strategy and methodology used in the formulation of this plan was developed by the research people of ICA.

Agricultural Research in Colombia: Institutional Infrastructure and Present Orientation

This part of the paper presents the results of a study conducted by the International Development Research Centre (IDRC) on the way in which resources (financial resources in particular) are allocated for agricultural research in Colombia.[2] The study focused on six institutions and the university sector. The institutions analyzed were: Instituto Colombiano Agropecuario (ICA) (The Colombian Agricultural Institute); Centro Nacional de Investigaciones del Café (CENICAFE) (The National Coffee Research Institute); Corporación Nacional de Investigación y Fomento Forestal (CONIF) (The National Research and Forestry Development Corporation); Corporación Autónoma Regional del Cauca (CVC) (The Cauca Valley Corporation); Centro Internacional de Agricultura Tropical (CIAT) (The International Tropical Agriculture Centre); and Instituto Nacional de los Recursos Renovables y del Ambiente (INDERENA) (The National Institute of

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[2] IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

National Resources and the Environment). Information on universities doing some type of agriculturally related research was also examined and summarized. ICA was the most important institution studied; being the leading agricultural research centre in the country. It is important to note that this study only considered financial resources spent on agrobiological research.

Expenditure in Agricultural Research

Research and Development Expenditure at the National Level

Table 1 shows the total amount of financial resources that the six institutions studied spent on research from 1972–1976.[3] ICA's share of total research expenditure during this period was 83.5%. However, the table indicates that ICA's share has declined in recent years; in 1973, it accounted for 84.8% of total resources spent on agricultural research, but in 1976 this percentage dropped to 80.3%. During this same period, CENICAFE occupied second place in terms of research expenditure with 10.0%. INDERENA spent an average of 3.0% of total resource expenditure during this period and universities accounted for 3.6%. The CVC share made up no more than 0.9% of the total. Table 1 also shows that although total agricultural research expenditure increased from 1972–1976 (in current values), in real terms (at constant 1970 values) there has been an overall decline in the amount of funds allocated for research.[4]

Table 2 shows the breakdown of agricultural research expenditure in terms of crops and agricultural products, as well as the relationship between research expenditure and value of production for each product. In most cases, the percentage of research expenditure over the value of production is less than 0.20%, with a few extreme exceptions (i.e., oats and sheep) in which the high percentage is due to the small value of that crop's production in the country. In those cases, even a modest research expenditure represents a high percentage in terms of this relationship.

Two additional factors should be pointed out with respect to Table 2. Firstly, the research expenditure figures for the different crops slightly underestimate the investment level in each crop because these amounts only include the cost of the respective research programs but do not include the maintenance costs and investments related to the research stations and centres in which the programs are carried out. This latter aspect appears as a separate expenditure in Table 2. At the aggregate level, total agricultural research expenditure represents 0.33% of the total value of agricultural production in Colombia (with only slight variations between 1972 and 1976).

Secondly, a more significant relationship to analyze is that of agricultural research expenditure as a percentage of the agricultural gross domestic product (GDP) because the latter only includes the value added by this sector. Nevertheless, the breakdown of agricultural GDP in terms of the different crops and agricultural products is not available.

At the sectoral level, Table 3 shows the evolution of the relationship between total agricultural research expenditure and the GDP of the country. This table clearly shows the deterioration of the proportion of agricultural GDP that is allocated to research in this sector. In 1972, this proportion was 0.32%, which was substantially higher than the overall relationship between total national research and development expenditure (for all sectors) and total GDP (estimated by COLCIENCIAS to be 0.20% in 1972). By 1976, this situation had changed drastically, with agricultural research expenditure dropping to 0.22% of agricultural GDP. A somewhat less negative evolution is observed with respect to total GDP (Table 3) and total value of agricultural production (Table 2).

Distribution of Research and Development Expenditure in ICA

Table 4 shows how the distribution of ICA research funds has evolved from 1970–1978. Research activity has tended to decline. Even though total ICA expenditures have increased in real terms, allocations for research have dropped in real terms by $21 000 000 or 17.0%. Research went from constituting 41.1% of the total ICA budget in 1970 to 27.7% in 1978.

A breakdown of the total ICA budget during the period in question shows that this institution has been increasingly assigned more duties but has not received a proportionate increase in budget funds. Consequently, the institute's departments compete for available resources; research, formerly the most important ICA activity, has been negatively affected by this situation in terms of being able to sustain the pace of research projects, undertaking new projects in response to emerging agricultural needs, and losing qualified staff.

[3] To convert from Colombian pesos to U.S. dollars, the following rates of exchange should be used for the different years: 1970, $18.45 Colombian pesos for U.S. $1 (this rate should be used for all amounts given in constant 1970 values); 1972, $21.87; 1974, $26.06; 1976, $34.70; and 1978, $39.10.

[4] This does not include CIAT expenditures in this area because CIAT is an international agency and the information would distort the national research picture.

Table 1. Total expenditure on agricultural research (thousands of Colombian pesos).

Institution	1972	1973	1974	1975	1976
ICA	151200	175500	188100	236700	266700
CENICAFE	—	15674	23881	31584	37227
INDERENA	—	9047	9481	9503	9023
CONIF	—	—	—	3053	2813
CVC	—	—	—	1928	3136
Universities	4576	6776	7143	10812	13401
Total	155776	206997	228605	293580	332300
Total (in constant 1970 values)	124422	135469	117233	124610	114114

Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

ICA research can be divided into two categories: agricultural and livestock. These categories can be further divided into basic research and research on specific products. Basic research, which will not be discussed here, includes crop production, grasses and fodder, and special projects.

Table 5 shows that agricultural research represented more than half of the total resources spent by ICA on research. Product research, rather than basic research, predominates in both the agricultural and livestock categories. A brief discussion of these research areas follows.

(1) Agricultural product research.[5] The most important subgroup, in budget terms, in the agricultural product research category is grains and cereals. Table 6 indicates that the maize and sorghum program is the main program[6] because its share in total ICA budget expenditure for the given period is the highest. Rice and wheat are second and third, respectively, after maize and sorghum.[7] These are the most important products in economic terms when you consider the area sown with them and their production value. These products also receive the highest research priority.

The potato and cassava program has also received significant budget allocations, placing it second after the cereal and grain program. These two products also have a substantial share of production value. Over the last 5 years, ICA has increased budget allocations for the fruit and vegetable program because it covers essential food items regarded as high priority in integral rural development plans and food and nutrition programs.

Research on "panela" (sugar loaf) also appears important among total research expenditures as a result of the concern the government has shown for this basic subsistence crop that is grown in five regions of the country.

Finally, it is important to note that although some products, such as bananas, represent a considerable part of the production value, ICA has not given them top research priority. This particular commercial crop (bananas) is primarily used for export.

(2) Livestock research by product. The dairy and beef programs account for a significant share of ICA research funds spent on livestock programs/products (Table 7). The pork program is third in terms of budget allocations for livestock research but shows the highest growth rate, whereas the products that are first and second show negative growth rates.

(3) Basic agricultural and livestock research. Tables 8 and 9 provide information on basic research in these two fields. The soil and plant pathology programs are first in basic research. Entomology and plant physiology are allotted a smaller share of funds for basic research. Generally speaking, priority has been given to those disciplines that aim at controlling both plant and animal pests and diseases.

Implicit Research Priorities for Agricultural Products in ICA

On the basis of Table 6, implicit research priorities for agricultural products can be identified according to the amount of funds spent: (1) high priority: maize and sorghum, perennial oleaginous products, potatoes and cassava, fruits and vegetables, and rice; (2) medium priority: legumes and

[5] This analysis of research expenditures and economic importance does not include coffee, which is the principal agricultural product in the economy. The National Federation of Coffee Growers conducts research on this product, which receives the largest amount of research funds.

[6] Estimates indicate that almost 80% of the activities in this program are focused on maize.

[7] Although wheat is an important cereal, it is not very important in terms of the amount of funds allocated to it for research. At the economic level, its contribution to production value is not significant. Maize has fundamentally become an imported product.

Table 2. Relationship between research expenditures and value of production by agricultural product (thousands of Colombian pesos).

Product	Value of production (A)					Research expenditure (B)					B/A (%)				
	1972	1973	1974	1975	1976	1972	1973	1974	1975	1976	1972	1973	1974	1975	1976
Coffee	6701590	8540240	10446400	13707100	27189640	350[a]	10155	12294	16123	15506	—	0.119	0.118	0.118	0.057
Rice	1880230	3808710	5668660	6315580	6405360	2834	2979	2884	4380	5452	0.151	0.078	0.051	0.069	0.085
Oats	—	1760	2160	3900	3700	758	1667	1147	637	704	—	94.716	53.102	16.333	19.027
Barley	201586	247476	354147	660386	444886	758	1021	897	925	704	0.376	0.413	0.253	0.140	0.158
Maize	1749450	2460130	2662600	2964820	4288590	4934	5602	6901	6732	7522	0.226	0.173	0.185	0.161	0.125
Sorghum	432390	778400	1069970	1205660	1750000										
Wheat	173968	202358	264364	251527	290554	1501	1931	2790	3648	4021	0.863	0.954	1.055	1.450	1.384
Potato	1190880	5703490	2241580	5335440	4478260	4053	4196	4292	5994	6724	0.098	0.050	0.063	0.050	0.064
Cassava	2945730	2635360	4579320	6572290	6045710										
Yam	—	182597	178448	243975	281766	—	—	—	—	—	—	—	—	—	—
Sugarcane	920112	—	—	—	—	1137	1268	1071	1675	270	—	—	—	—	—
"Panela"	1987290	2814240	2524120	2710040	7562820	—	—	—	1772	4749	—	—	—	0.065	0.063
Cotton	2107470	2948910	3937790	4120030	6894300	2436	2258	2069	2625	3011	0.116	0.077	0.053	0.064	0.044
Sesame	147698	110555	177315	239685	271411	4058	5117	5158	7417	7784	0.839	0.532	0.319	0.364	0.494
Peanuts	—	3213	5313	14250	18260										
African Palm	—	427328	740765	612304	683038										
Soybean	336210	421562	691638	1172180	603900										
Vegetables and fruits	—	—	—	—	—	4456	5005	4578	6878	7754	—	—	—	—	—
Sisal Hemp	—	—	—	—	—	—	—	—	—	270	—	—	—	—	—
Cocoa	288180	423589	565915	616812	889104	2764	3620	3282	4587	4749	0.959	0.855	0.580	0.744	0.534
Tobacco	298800	609800	673056	1154200	1088800	1098	1099	1297	2062	2108	0.367	0.180	0.193	0.179	0.194
Grain legumes (beans)	504136	523935	913097	1667100	1388570	2975	3726	4287	4662	4908	0.590	0.711	0.470	0.280	0.353
Bananas	600000	1051180	1473360	1857670	2963010	952	1358	1388	1772	2082	0.038	0.041	0.030	0.025	0.023
Plantain	1918130	2251380	3178340	5101820	6082110										
Cattle	13205720	14543200	18329420	16773310	18165494[a]	8717	9740	9515	14048	15652	0.066	0.067	0.052	0.084	—
Pigs	2219000	3510900	3318400	5517400	7476077[a]	2580	3404	2679	4875	9261	0.116	0.097	0.081	0.088	—
Sheep	30799	40340	54300	84110	92310	1887	2132	1960	2577	2929	6.127	5.285	3.610	3.064	3.173
Poultry	3582720	5001300	6820710	8577250	11476360[a]	2726	3386	2439	5684	5103	0.076	0.068	0.036	0.066	—
Minor species	—	—	—	—	—	—	—	100	387	1332	—	—	—	—	—
Forestry	927000	1216000	1770000	1950000	2668000	200	200	267	3937	4222	0.022	0.016	0.015	0.202	0.158
Fishery	915000	1036000	1598000	1920000	2534000	1608	11819	12503	15197	15294	0.176	1.141	0.782	0.792	0.604
Basic research						24361	29211	31053	42868	48116					
Support research						10319	14699	15746	20963	28412					
Operation research centres						68314	80203	96476	108520	121313					
Total	45264089	61493953	74239688	91348839	122036030	155776	206997	228605	293580	332300	0.344	0.337	0.308	0.321	0.272

[a] Estimated.

Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

Table 3. Relationship between total agricultural research expenditures and gross domestic product (total GDP and agricultural GDP) (thousands of Colombian pesos).

Year	Total agricultural research expenditure (A)	Total GDP (B)	Agricultural GDP (C)	A/B (%)	A/C (%)
1972	155776	186092300	49465000	0.08	0.32
1973	206997	243235900	66746000	0.09	0.31
1974	228605	329155400	88477600	0.07	0.26
1975	293580	412828700	113484800	0.07	0.26
1976	332300	532960800	148956300	0.06	0.22

Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

Table 4. Distribution of the ICA budget in different activities (millions of Colombian pesos).

Activity	1970	1971	1972	1973	1974	1975	1976	1977	1978
Administration	43.6	43.1	47.3	49.9	51.9	88.8	92.3	106.7	137.8
Debt service	—	0.1	1.9	6.8	12.4	28.6	60.6	63.9	73.8
Rural development	51.0	57.9	69.3	89.4	103.0	117.2	149.1	199.3	301.8
Research	121.3	143.6	151.2	175.5	188.1	236.7	266.7	307.8	420.4
	(121.3)[a]	(130.0)	(120.8)	(114.9)	(96.5)	(100.7)	(91.6)	(88.4)	(100.9)
Agricultural production	16.0	21.5	30.8	36.3	43.3	52.9	62.5	78.4	88.9
Livestock production	26.1	44.0	55.4	73.6	89.2	151.8	171.7	162.7	230.5
Physical investments and others	37.1	54.6	56.1	13.7	18.7	32.2	40.6	99.2	262.1
Total	295.1	364.8	412.0	445.2	506.6	708.2	843.5	1018.0	1515.3
	(295.1)	(332.2)	(329.1)	(291.6)	(259.8)	(301.4)	(298.7)	(292.2)	(363.7)

[a] Figures in parentheses are expressed in constant 1970 values.
Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

annual oleaginous products, sugarcane for sugar loaf (panela), cocoa, cotton, wheat, and tobacco; (3) low priority: plantains and bananas, sugarcane, barley, and oats.

Human Resources in Agricultural Research

General Trends in the Development of Human Resources

An ICA study[8] showed that the evolution of this institution's human resources has two main characteristics:

(1) In 1974, the research department of ICA had the highest concentration of university-trained professionals in the institution, either at the bachelor, M.S., or Ph.D. levels. By 1979, the relative importance of this department in terms of the number of professionals working in it had diminished (Table 10).

(2) Although most of the M.S. and Ph.D. holders working in the institute work in research, the percentage of them working in this area has been on the wane.

Brain Drain: Migration of Researchers[9]

Between 1960 and 1978, 652 persons were trained at the M.S. and Ph.D. levels. Of this group, 396 professionals were still working in ICA in 1978 and 256 had left. More importantly, the number of graduate level professionals who have left ICA has increased more rapidly than the number who have been hired.

[8] ICA. 1979. Diagnóstico de la investigación agropecuaria. Three volumes. (Unpublished).

[9] Based on the document: IICA. 1979. Sistemas nacionales de investigación agropecuaria en América Latina: análisis comparativo de los recursos humanos en países seleccionados. El caso del Instituto Colombiano Agropecuario (ICA). Volume III.2.

Table 5. Percentage participation of agricultural and livestock research in total research expenditures of ICA.[a]

	Agricultural research			Livestock research				
Year	Research programs on crops	Basic research	Total	Program product	Basic research	Other	Total	Support research[b]
1972	41.3	17.6	58.9	19.2	9.5	4.2	32.9	8.3
1973	39.4	16.2	55.6	18.8	11.2	2.5	32.5	11.8
1974	40.0	18.1	58.1	16.3	10.9	3.8	31.0	11.0
1975	38.2	17.3	55.5	19.1	11.2	4.3	34.6	9.9
1976	36.3	16.2	52.5	19.8	11.3	5.0	36.1	11.4

[a] Does not include the operational costs of agricultural research stations.
[b] Includes biometry, agricultural resources, agricultural machinery, regional agricultural economy, etc.
Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

A recent study on the evolution of the human resources in ICA shows the following trend:[10]

	Researchers at graduate level (A)	Researchers leaving ICA (B)	B/A (%)
1960–67	63	2	3.2
1968–74	186	50	26.9
1975–78	104	55	52.9

Thus, there is a definite trend toward higher migration of researchers, coupled with less hiring of research staff. If this trend continues, the number of skilled researchers leaving the institute will outnumber those entering and ICA will suffer a net loss of highly trained graduate level staff.

Conclusions

This brief analysis of the situation of agricultural research in Colombia clearly points out three important trends that are having a negative impact on the sector:

(1) Funds allocated for agricultural research (both at the national level and in ICA) have been decreasing in real terms (in constant 1970 values) over the last decade (Tables 1, 4). This trend is also evident in the deterioration of the proportion of agricultural GDP that is allocated to agricultural research (Table 3).

(2) During the period under analysis, ICA has been increasingly assigned more duties but has not received a proportionate increase in budget funds. Consequently, the institute's departments compete for available resources. Research, formerly the most important ICA activity, has been negatively affected by this situation, both in terms of funds allocated to it within the ICA budget (Table 4) and in terms of

Table 6. Percentage participation of each crop in total research expenditure of ICA.

Crop	1972	1973	1974	1975	1976
Cereals	*13.0*	*13.2*	*14.5*	*11.5*	*11.1*
Rice	3.4	3.0	2.9	3.1	3.3
Oats	0.9	1.7	1.1	0.4	0.4
Barley	0.9	1.0	0.9	0.6	0.4
Maize and sorghum	6.0	5.6	6.8	4.8	4.6
Wheat	1.8	1.9	2.8	2.6	2.4
Starchy Crops	*6.1*	*5.6*	*5.6*	*5.5*	*5.4*
Potatoes and cassava	4.9	4.2	4.2	4.2	4.1
Plantain and bananas	1.2	1.4	1.4	1.3	1.3
Sugars	*1.3*	*1.3*	*1.1*	*2.5*	*2.9*
"Panela" (sugar loaf)	—	—	—	1.3	2.9
Sugarcane	1.3	1.3	1.1	1.2	—
Oil Seeds	*7.8*	*7.4*	*7.1*	*7.2*	*6.5*
Perennial	4.9	5.1	5.1	5.3	4.7
Cotton	2.9	2.3	2.0	1.9	1.8
Other Crops	*13.0*	*11.9*	*11.7*	*11.7*	*10.5*
Cocoa	3.3	3.6	3.2	3.3	2.9
Vegetables and fruits	5.0	4.0	3.5	4.0	3.7
Grain legumes and annual oil seeds	3.4	3.2	3.7	2.9	2.6
Tobacco	1.3	1.1	1.3	1.5	1.3
Total[a]	41.3	39.4	40.0	38.2	36.3

[a] Refers to the total percentage allocation to research programs on crops (Table 5).
Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

[10] IICA. 1979. Sistemas nacionales de investigación agropecuaria en América Latina: análisis comparativo de los recursos humanos en paises seleccionados. El caso del Instituto Colombiano Agropecuario (ICA). Volume III. 2, 36–38.

Table 7. Percentage participation of animal products in total research expenditures of ICA.

Animal program product	1972	1973	1974	1975	1976
Beef cattle	4.3	3.8	4.0	4.9	4.5
Dairy cattle	6.3	6.0	5.4	5.0	5.0
Pigs	3.1	3.4	2.5	3.2	5.4
Sheep	2.3	2.1	1.9	1.8	1.8
Poultry	3.3	3.4	2.4	4.0	2.9
Minor species	—	—	—	0.2	0.3
Total[a]	19.2	18.8	16.3	19.1	19.8

[a] Refers to the total percentage allocation to program-product livestock research (Table 5).

Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

Table 8. Percentage participation of main disciplines related to basic agricultural research in total research expenditure of ICA.

	1972	1973	1974	1975	1976
Entomology	3.4	2.1	3.2	2.6	2.9
Plant physiology	3.1	3.0	3.0	2.6	2.6
Plant pathology	4.4	4.5	4.9	4.5	4.2
Soils	6.7	6.6	7.1	7.6	6.4
Total[a]	17.6	16.2	18.1	17.3	16.2

[a] Refers to the total percentage allocation to basic agricultural research (Table 5).

Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

Table 9. Percentage participation of main disciplines related to basic livestock research in total research expenditure of ICA.

	1972	1973	1974	1975	1976
Animal physiology	0.8	0.9	1.2	1.0	1.0
Microbiology	3.6	4.5	4.5	3.9	4.1
Nutrition	0.8	0.9	1.0	0.8	0.7
Parasitology	1.5	2.0	1.5	1.8	1.1
Pathology	2.3	2.5	2.1	2.1	2.2
Toxicology	0.4	0.5	0.7	0.5	0.5
Epidemiology	—	—	—	0.2	0.4
Vascular diseases	—	—	—	1.1	1.3
Total[a]	9.5	11.2	10.9	11.2	11.3

[a] Refers to the total percentage allocation to basic livestock research (Table 5).

Source: IDRC. 1980. Project ARIAL. Asignación de recursos para investigación en América Latina. Colombia: estudio de caso.

high-level manpower dedicated to research in the institution (Table 10).

(3) Despite the effort made to train high-level manpower for research (M.S. and Ph.D. levels) carried out in the sixties and early seventies, ICA is facing an increasing problem of migration of researchers, coupled with less hiring and training of research staff. If this trend continues, its capacity to conduct research will be seriously impaired in the very near future.

It is in response to this deteriorating situation that the National Agricultural Research Plan was formulated. The plan is part of a broader package of government action aimed at changing the situation and stopping the downward trends. Two other important measures that form part of this package are the creation of a Special Fund for Agricultural Research (different from, and additional to, the ICA budget) and the establishment of a National Council for Agricultural Research and Technology Diffusion. These two measures are presently being considered in the Ministry of Agriculture and in Congress.

It should also be pointed out that the design and establishment of a Special Fund for Agricultural Research raises the important issue of identifying alternative financial mechanisms or systems for funding agricultural research within the country. The national budget has been the traditional source of research funds for this sector, given the centralized institutional model that has operated mainly around one large public research organization. For the creation of the special fund, alternative mechanisms for the mobilization of financial resources are being considered. This also raises the issue of the participation of the private sector in agricultural research and of mixed or joint research mechanisms between the public and private sectors.

A General Approach to the Process of Identifying Research Priorities in the Agricultural Sector

The formulation of research policies, in any field, is a way of responding to a situation in which multiple possible research topics compete for the limited financial resources that are available for supporting such activity. Furthermore, they are also a means for relating the research effort in any given country to the needs and development problems that are of major importance in that society. Research policies are also a means of influencing the characteristics and orientation of technical change and technological development in the agricultural sector, trying to make it more compatible with the "type of development" (or development objectives)

Table 10. Professional personnel by level of education in ICA.

Department	Bachelor's degree			M.S.			Ph.D.			Total		
	1974	1976	1979	1974	1976	1979	1974	1976	1979	1974	1976	1979
Research	406	205	137	77	155	145	34	32	39	517	392	321
Rural development	256	190	149	22	76	88	1	7	6	279	273	243
Livestock production	279	220	120	14	23	26	2	4	2	295	247	148
Agricultural products	120	95	42	8	26	24	2	3	2	130	124	68
Transfer of technology	—	—	222	—	—	17	—	—	—	—	—	239
Administration and planning	106	64	59	17	23	20	2	5	2	125	92	81
Total	1167	774	729	138	303	320	41	51	51	1346	1128	1100

Source: ICA. 1979. Diagnóstico de la investigación agropecuaria. Three volumes. (Unpublished).

that are considered to be most appropriate for that society. This third aspect leads to the broader issue of a "technological development policy" for the agricultural sector, of which the research policy is only one of several components. The orientation of technical change and technological development in the agricultural sector will depend, to a large extent, on a broad range of decisions that are made either by governments or by the producers themselves (at the level of the production units), such as decisions relating to what products should be produced in the country and which ones should be imported, what technologies should be made available or should be used, and what production systems should be promoted (i.e., cropping systems, size and type of production units, etc.). It is through these and other decisions that the "technological profile" of the agricultural sector will be determined and the dynamics of technical change will gradually take form.

Although the supply of technical knowledge generated by research programs is one of the factors that may influence these decisions (i.e., by making some alternatives possible or feasible), most often they are influenced by economic policies or market situations (both the national and international market) that confront the producer. Thus, many of the decisions are shaped by credit, commercialization, fiscal, monetary, and foreign exchange policies and foreign trade. These policies may also influence the relative importance that is given to national agricultural research efforts in any given period, and thus the financial resources that are allocated to agricultural activity. The role assigned to the agricultural sector in the development process by governmental policies (i.e., its relationship to industrialization and other developmental policies) also plays a major role. A preliminary analysis of the role played by some of these economic policies in Colombia is outlined later in this paper.

The previous considerations clearly point out that the agricultural research policy in any country is only one of the components of the technological development policy of that sector. This paper only addresses methodological issues related to the formulation of a research policy for the agricultural sector, with marginal references to the interphase of research policies with technological development considerations and economic policies that are of relevance to the sector.

At the most general level, research priorities can be derived from three major sources or considerations:

(1) Socioeconomic development policies and programs of a country, both at the global (i.e., general development programs, foreign trade policy) and sectoral levels (i.e., agricultural development policies, programs, and priorities). The objective is to link research efforts with the development objectives and priorities of a country.

(2) Specific needs or requirements that may be identified, both in terms of general needs of the country (i.e., the need to supply certain kinds of food for a specific sector of the population or the need to make better use of local food crops or natural resources) and specific requirements or problems related to agricultural production (i.e., the need to solve specific technological constraints that limit productivity in certain areas).

(3) Prospective considerations with respect to future agricultural needs, future expected situations of national and international agricultural markets, and the type of agricultural production system or food system one would like to develop in the future.

The importance of the first factor will depend on the existence of explicit and clearly defined agricultural development policies and programs in any given country. If these do not exist or if they are formulated only in vague and general terms (without specific priorities, development objectives, and production targets), as is quite often the case, this factor will play a smaller role in determining research priorities.

Nevertheless, even when explicit sectoral policies and development programs are clearly formulated, the criteria and guidelines derived from them should be complemented by the other two factors. The second factor may lead to the identification of requirements or production possibilities that are not adequately dealt with in the present sectoral development programs, such as the need to develop a "cropping systems" approach or the possibility of promoting greater use of traditional food crops existing in the country. If these requirements or possibilities are identified, they should be taken into consideration in order to correct possible gaps in the sectoral development plans.

Finally, both existing needs and sectoral development plans are normally conceived in terms of the present and very near future. Medium- and long-term perspectives are quite often absent from these considerations, or they play only a marginal role. The third factor is the most difficult to cope with, both in sectoral development planning efforts and in the identification and formulation of research priorities. The Colombian experience analyzed in this paper deals mainly with the first two factors. The prospective approach has not played a major role in this planning effort.

Methodological Framework for the Identification of Research Priorities

The formulation of a research policy for the agricultural sector involves three major levels of analysis:

(1) The identification of agricultural products or crops that have high socioeconomic importance or priority for the development of the country. The present or potential socioeconomic importance of certain crops is one of the criteria that may lead to the identification of research priorities but by itself does not define research priorities. Research areas are defined not only in terms of agricultural products or crops but also in terms of production problems or rural development issues, such as agricultural machinery and implements, irrigation technology and water supply, conservation and storage of crops, etc.

(2) Having identified agricultural products or crops that have high socioeconomic importance, the next step is to define which of them should receive major attention from the point of view of research. Given a situation of limited financial resources, not all products with present or potential socioeconomic importance can be covered by the research establishment of any country. This raises the following questions: Which products should be produced in the country and which should be imported? Which products face identifiable "technological constraints" that limit productivity and may lead to important research problems? Should the technology be generated internally (i.e., improving traditional or existing technologies) or should it simply be imported and adapted? Which products (research areas) should receive more support from government funds and which ones should be left to the initiative (and financial support) of the private sector? This last question is important in those countries where the private sector plays (or may play) a role in agricultural research. This second step narrows the range of products or production problems identified as important in the first step. Some of these questions imply political decisions (policy decisions).

(3) The third step consists of identifying or defining research topics or issues that are important for the solution of the technological constraints that limit production or productivity levels in the crops that have been selected. It is only in this third level of analysis that research priorities are actually formulated.

The preceding considerations define a general framework for the identification of research priorities and technological development objectives that is summarized in Fig. 1. The output of the socioeconomic considerations is the identification of (adjusted) socioeconomic product or problem priorities for research purposes.[11] The technological considerations of the process consist of the identification of technological requirements or problems within the selected products or problem areas that may lead to the identification of specific research needs (and, therefore, research priorities). The starting point for this analysis is the identification of the principal technological constraints that limit production or productivity levels of specific crops under identifiable circumstances. Technological constraints refer to physiological, environmental, or pathological factors, as well as management systems and farming practices, that are presently an obstacle to increasing production levels or improving the efficiency of resource utilization in specific crops or products (or even having a negative effect on these aspects).

The research effort that will have to be carried out in order to solve the technological constraints identified will depend not only on the socioeconomic

[11] It should again be emphasized that these may be slightly different from the priorities that may emerge from using only economic indicators.

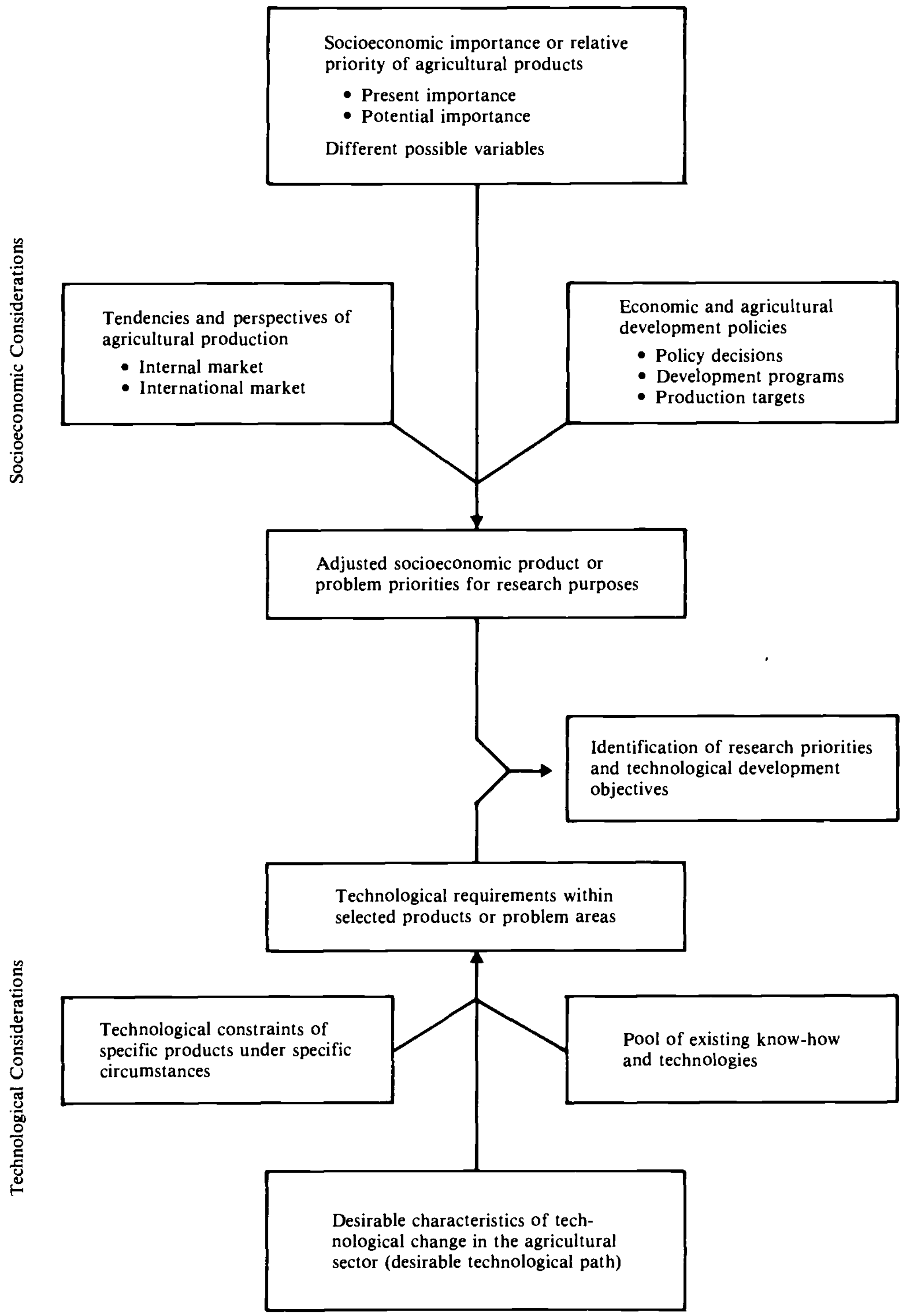

Fig. 1. Methodological framework for the identification of research priorities.

importance of the product but also on the difficulty or magnitude of the technological problem that is confronted. For example, in cases where the level of technological development (technological conditions of production) is considered to be acceptable for a specific crop in a given country, only research at a level necessary for maintaining existing high yields or disease-resisting varieties will be necessary (even for a high-priority crop). The research effort required (and the research priority) would be much higher, on the other hand, if important technological constraints are identified in a high-priority product. Thus, the order of product priority assigned on the basis of socioeconomic considerations can be altered or modified in view of technological considerations. It is for this reason that in Fig. 1, the final research priorities and the technological development objectives are derived from both types of considerations.

In Colombia, two analytical models are being simultaneously considered (and experimentally applied) in the process of defining socioeconomic product priorities for research purposes. These two models, although they can be used in a complementary manner, are based on a different set of variables or indicators for the identification of socioeconomic priorities.

The first model uses jointly, and tries to relate, two major criteria for priority identification: the comparative advantage a country has in producing a given crop and the participation of that crop in national food consumption or total family budget (argument of food security). Furthermore, this model uses the concept of price-demand elasticity to determine which products should receive higher priority in governmental support for research related to them and which product should be left to the initiative and funding of the private sector.

The second model uses as the main criteria the participation of each crop in the "total circulation of agricultural production" (this includes production for the internal market, exports, and imports of agricultural products). Besides these production variables, two additional indicators are taken into consideration to see if the model gains in analytical or discriminatory power (by substantially modifying the priorities initially identified). These are rural employment generated by each crop and the extension of land under a given crop's production.

The first model is more conceptually sophisticated and takes into consideration a broader range of factors, including major policy decisions that have to be made as part of the process of identifying priorities (i.e., export orientation versus food security and public versus private funding of agricultural research). On the other hand, however, it requires much more data, as well as the utilization of such concepts as "shadow prices" and the social costs of the use of domestic resources (land, capital, and labour).

The second model is much simpler and only requires data that is easy to use and readily available in any country. Its major assumption is that the participation of a crop in the total circulation of agricultural production has such close interrelationships with several other aspects or indicators of agricultural production (i.e., extension of land under that crop's production, total agricultural production, etc.) that it may be used as a significant approximation of socioeconomic importance or priority in terms of products. For example, the two additional variables to be discussed later do not add much to the priority ranking established by this basic criteria.

To identify technological requirements or problems within selected products or problem areas and derive research priorities from these requirements, ICA established a series of working groups covering the main crops that are produced in the country. The working methodology that was used has two main characteristics: (1) a matrix approach that tries to identify technological constraints on specific crops under certain environmental conditions that define ecologically homogeneous zones; in order to use this methodology the country was regionalized and divided into ecological zones; and (2) the use of the delphic technique, at the level of the different working groups, to identify and analyze the technological constraints and research needs that are faced by each crop.

The output of this process has been the formulation of "research programs" for the different crops or agricultural products under consideration. The set of research programs thus formulated, with a few other components related to general policy issues, constitute the "National Plan for Agricultural Research."

Some Observations with Respect to the Application of this Methodological Framework in Colombia

It should be noted that the two main phases of this planning process (i.e., the identification of socioeconomic product or problem priorities and the determination of technological requirements and research needs within selected products or problem areas) are supposed to be carried out in chronological order, i.e., the determination of technological requirements and research needs within products or problem areas should be carried out only for those products and problems identified as having high (or significant) socioeconomic importance for the country. This, of course, implies that the policy decisions that are raised by the two models have been coped with and answered.

Nevertheless, the sequence of events in real life situations does not always follow the logical ordering of methodological steps. In fact, the two phases of this planning process may overlap and be carried out simultaneously or in parallel fashion, as in Colombia. In this case, ICA decided to go into the identification of technological requirements and research needs at the product level (second phase), although there was still much ongoing discussion as to which were the agricultural product and problem areas that could be considered to have high socioeconomic importance. The two models were developed in response to this issue, but even though the first phase is still an ongoing process in Colombia (the two models are being experimentally applied), ICA has already finished formulating a first version of the research programs that should be carried out at the level of each product. Thus, the methodology of the second phase has already been tried out and empirically tested, having reached the stage of producing a first version of possible research programs at the product level.[12]

The analysis of the reasons for the discrepancy between the methodological framework or approach that has been presented and its actual implementation in Colombia gives an interesting insight into the dynamics of the planning process and into some of the practical problems that it faces.

When this planning process started, it soon became clear that although the determination of technological requirements and research needs within products (second phase) was, basically, a technical endeavour, which could be easily implemented if the necessary information was available, the identification of socioeconomic priorities (first phase) involved policy decisions with respect to the criteria (model) to be used and with respect to substantive economic policy issues. This being the case, the decision-making process with respect to the latter component proved to be much slower and more difficult than had been expected. Consequently, it took some time to develop and discuss the two models that are presented.[13]

In order not to stop the process of identifying research priorities and formulating research programs at the product level, until the basic issue of defining socioeconomic priorities was settled (which could become a vicious circle), an alternative route was taken. It was decided to use a list of 28 products that the Ministry of Agriculture (OPSA) had drawn up, which represents almost the total agricultural production within the country and for which there is information on production and commercialization. In fact, the 28 products represent 97% of total agricultural production. The process of identifying technological requirements and research needs within specific products (second phase) was carried out for all 28 products.

The implications of this operational decision are obvious. Because the 28 products do not reflect any evaluation of socioeconomic priority (it is merely a list of the products that are being produced in the country), the proposed research programs cover almost the total range of agricultural production and, therefore, the total range of possible research topics in terms of products.[14]

Despite this limitation, the alternative was adopted for the following reasons:

(1) The procedure does not invalidate the effort of identifying technological constraints and research needs within products (second phase). It merely made it a more manpower-intensive and costly process because the exercise was carried out not only for high-priority products but for almost all products. On the other hand, however, it was considered that this planning exercise would produce valuable information on technological constraints and problems that are faced by agricultural production within the country (even for low-priority products).

(2) Because socioeconomic product priorities have not yet been established due to the difficulties encountered in the first phase), the first version of the National Plan for Agricultural Research suggests a resource-allocation procedure (and thus implicit priorities) in terms of the relative importance of each product from the point of view of its participation in the total agricultural production at the present time, and in terms of the need to create a basic research infrastructure in some research areas (requiring higher investment levels).

(3) It was considered that the result of establishing explicit socioeconomic product priorities (once the first phase of this methodological process is completed) could be incorporated a posteriori into the final version of the National Plan for Agricultural Research by modifying, accordingly, the respective importance given to the different research programs for resource-allocation purposes and, if necessary,

[12] See Plan nacional de investigación agropecuaria del ICA. 1981. Five volumes.

[13] Because the two models were only recently developed, final policy decisions with respect to the priorities that emerge from them in the Colombian case are still pending.

[14] With the exception of coffee and sugarcane, which in the case of Colombia are research areas that are in the hands of the private sector.

by eliminating those programs for low-priority products.

Thus, the Colombian experience shows complex interaction between the two major phases of the methodological framework presented, given the need to adapt formal procedures and methodological steps to the realities and conditions of the planning process within each country.

Identification of Socioeconomic Priorities in Terms of Products

Identification of Socioeconomic Priorities in Terms of Comparative Advantages and Food Security

The theory of induced technological change, endogenous to the economic system, suggests that the relative price of factors affects both the choice of existing technology as well as the biases in the use of factors in the new production functions. It has been shown empirically that the different paths of technological development taken by the United States and Japan have been determined by the relative price of factors that reflect the different endowments these countries have in terms of land and labour.

In underdeveloped countries, it has been found that when governments establish the price of goods and factors without taking into account a country's endowment of factors, patterns of technological change are not compatible with a country's comparative advantages. In many developing countries, government policies undervalue certain kinds of products and overvalue others; the result is that errors are made in allocating resources for production.

Current economic theory has yet to explain why government makes this type of error in decision-making. Of course, government leaders have political commitments and the measures they take are politically motivated. The advocation of specific types of policy fundamentally depends upon the advantage political groups hope to gain from them. Thus, a ruling political group can impose its point of view and implement price policies and technological strategies that are incongruent with a country's particular endowment of factors.

Thus, political considerations filter down to decision-making levels where resources for research are allocated; these influences can significantly distort the process. Therefore, the evolution of overall development policies, especially those policies related to agriculture, must be considered when trying to find an explanation of how funds for agricultural research are allocated.

Economics has assigned agriculture certain functions in the economic development process. They include: (1) increasing the available food supply and freeing the labour force to work in nonagricultural sectors; (2) expanding the available market for industrial products; (3) increasing domestic savings; and (4) providing foreign exchange through agricultural exports.

The analysis of closed economies generally contains the first three points. However, when dealing with an open economy and when confronted with the fourth point, the other points no longer relate to domestic agriculture alone and could even become incompatible. The concept of comparative advantage is the relevant concept, in open economies, to evaluate efficiency or inefficiency in the allocation of resources. For example, in an open economy, it is not always desirable for a country to produce its own foodstuffs if the food could be acquired more cheaply in international markets. Therefore, the nutritional importance of a product, or other similar yardsticks, does not provide a basis for assessing the efficiency with which resources are allocated for research unless other criteria are considered such as international prices and the cost of the domestic resources needed to produce the same product; this includes knowledge of the opportunity costs of capital, labour, land, and foreign exchange. The concept of social costs of production and factors becomes important when considering economies that are riddled with distortions. For example, the market price of a product often does not represent its true social value; therefore, a person allocating resources on the basis of the production value alone can over- or underallocate resources; this will depend upon a country's current pricing policy, i.e., whether a specific product is under- or overvalued. This, in turn, depends on the priorities of the party in power.

A country may decide to ignore these considerations for political reasons or because it does not want to take risks and decides to guarantee the availability of food. Consequently, the country might allocate large quantities of resources for products that are important for the nutrition of its inhabitants. This means that at a given point in time the country in question does not have enough confidence in its ability to purchase the amount of foodstuffs it requires on the international market in order to avoid sharp fluctuations in domestic supply, or that even though a country has sufficient foreign exchange, it views food availability as essential to defending itself from outside political pressures.

The approach proposed here is one of an open economy in which the allocation of resources for research is based on comparative advantages and guaranteed availability of food or self-sufficiency in terms of the world market. This approach also allows for the distortions within an economy (subsidized credit, minimum wage, tariffs, subsidies, etc.) that fundamentally influence the way resources are spent. Special emphasis is placed on the repercussions of the macroeconomic policies and development model a government adopts on agriculture in general, and on the process of generating and adopting technological change in particular.

The Influence of Economic Policies on Agricultural Research Trends

The Colombian experience shows that agricultural policy, and technological policy as a subdivision of this policy, are determined in the long term by the development policies and models adopted by the government and are defined in the short and medium terms by the evolution of certain important macroeconomic aggregates.

During the period of rapid industrialization between 1950 and 1967, Colombia followed the import-substitution model, which tried to protect domestic production by establishing high tariffs and import quotas on consumer goods. Overvaluing the peso was another key tool in this policy and constituted, in effect, a tax on exports (primarily agricultural exports). During the 1960s, when the bias toward substituting imports grew stronger, taxes on agricultural exports ran from 17–47%. Another means of subsidizing industrialization was to force farmers to sell raw materials such as cotton to domestic producers at lower than international prices. In the short term, such measures acted to discourage the production of these goods, and over the long term, they inhibited the generation and adoption of technology. Only those products for which the country had a true comparative advantage, such as coffee, sugarcane, tobacco, and cotton, could withstand the pressures of this model.

At the same time, this model of rapid industrialization created the need for a large work force, which received stable or declining real wages. A major part of this salary is spent on food, so the model requires that there be an abundant supply of fundamental foodstuffs. The limited foreign exchange generated by the economy must be spent on importing the intermediate and capital goods necessary to boost the industrial process. Foreign exchange cannot be spent on importing food and agricultural raw materials. Therefore, credit, prices, and research policies for this period stressed the production of certain foodstuffs and the import substitution of certain raw materials.

In 1967, the import-substitution model gave way to the promotion of exports; trade policy and the exchange rate immediately reflected this situation. From 1970 onward, exports increased considerably, and higher international prices for coffee produced more foreign exchange and a relatively large surplus in the balance of payments. This situation brought about a change of priorities in the allocation of resources. First, the importance of products that had substituted for imports declined; more wheat, corn, sorghum, oil, and milk were purchased abroad. However, the excess amount of foreign exchange and its resulting monetization quickened the pace of inflation in Colombia and favoured stabilization policies in the short term, so that food imports became increasingly necessary. The energy crisis occurred during this same period and more money was spent to explore for new sources of oil and to develop alternate sources of energy (hydroelectric, nuclear, etc.). All of these activities demanded large amounts of resources from the national budget.

As a consequence of this, in the mid-1970s, the government was not only forced to curtail public spending to stabilize the budget, but most available resources went toward solving the energy crisis. In addition, with a surplus in the balance of payments, the government did not seek out foreign credit to finance research efforts. This brief description of the Colombian situation and its trade, fiscal, monetary, and exchange policies helps explain why, during certain periods, the level of resources earmarked for agricultural research decreased. It also helps explain why, at a given time, large quantities of resources flow toward certain types of products.

A Model for Identifying Product Priorities: Comparative Advantages and Food Security

When setting priorities among products for the allocation of research resources, several fundamental points must be considered: characteristics of the country's production system — relative availability of land, labour, capital, foreign exchange, and the social costs of each of these factors; availability of food and raw materials to meet nutritional needs and the country's industrial production needs; overall development models and policies; and financial resources available for agricultural research.

Because an open economy framework is being used and because one of the priorities of the Colombian Development Plan is to generate a stable flow of foreign exchange (anticipating later balance of payment problems), a basic criterion that must be used when allocating resources for research is the concept of comparative advantage. When a country has a comparative advantage in the production of a commodity, the net social return on producing an additional unit of the product is positive. In other words, the value of the product in terms of its shadow price (for marketable products, the border price, CIF, or FOB) should be higher than the social cost of the resource earmarked for its production.[15]

The comparative advantage can be calculated by using a parameter known as the domestic resources cost (DRC). It measures the social cost, in terms of domestic resources (land, labour, capital), of generating one additional unit of foreign exchange either by exporting or by substituting imports. This cost is then compared with the average cost in the economy of generating the same unit of foreign exchange (shadow exchange rate); if the quotient is less than 1, the country has a comparative advantage in this area.[16] For example, in 1978, it was estimated that the shadow exchange rate for Colombia was 36 pesos to the U.S. dollar. However, the domestic resources cost to substitute one dollar in maize imports was 45 pesos. In this case, Colombia did not have a comparative advantage in maize production.[17]

Using the cost structure of the different products and the percentage of imported inputs for these products, it is simple to calculate the DRC and the comparative advantage; this makes it possible to work out a scale that orders products according to their comparative advantage, using 1 as the dividing point.

Nevertheless, considerations of comparative advantages cannot be used as the only criterion for resource allocation. It is necessary to combine this criterion with food self-sufficiency or guaranteed food supply. This is especially important because the National Development Plan in Colombia places great emphasis on generating a sufficient supply of food for the people, as well as providing sufficient raw materials for agroindustry.

In order to be able to use the argument of food self-sufficiency as a criterion for setting product priorities, it is necessary to establish the weight (participation rate) that each product has in the total family budget. This is an indicator of their importance in terms of the food supply that has to be guaranteed in the country. For agricultural products used as raw materials in industrial processes (i.e., soybeans for oil), this information can be estimated by establishing the agricultural product's share in the cost structure of the industrial product, and multiplying this percentage by the industrial product's share in the total family budget.[18]

On the basis of these two criteria, it is possible to set up a graph of priorities. Comparative advantage will run along the horizontal axis and the importance of a product in family spending along the vertical axis (Fig. 2). The products in quadrants I and IV are those in which the country has a comparative advantage, and can export or substitute for imports efficiently. The products in quadrant IV, due to their low position in family spending, are the easiest to export. The products in quadrant I make up a significant part of the consumer's shopping basket, in addition to the comparative advantage the country has in their production. Therefore, quadrant I contains products that could efficiently substitute for imports or could be exported. The products in quadrant II have no comparative advantage but make up a significant part of the consumer shopping basket. The social return on the resources invested in promoting their production is low; this also holds true for the products in quadrant III, whose share in family spending is low. The products in quadrant II are importable or potentially importable. Quadrant III shows importable and domestic products whose share in family spending is not high.

The highest research priority should be given to the products in quadrant I because they have a comparative advantage (RSN > 0); they are also key items in the consumer's shopping basket. The products in quadrant III have the lowest priority. Government policy definition would provide the information necessary to establish the difference between quadrants II and IV. If the government de-

[15] The social return on a specific activity can be measured using the following formula:

$$RSN_j = \sum_{i=1}^{n} a_{ij} P_i - \sum_{s=1}^{m} F_{sj} V_s + E_j$$

where: a_{ij} = amount of the ith product produced by activity j; P_i = shadow price of this product; F_{sj} = amount of sth production factor used by j; V_s = social cost of the sth factor; and E_j = external effect produced by activity j.

[16] The domestic resources cost can be calculated using the following formula:

$$DRC_j = \left(\sum_{s=2}^{m} F_{sj} V_s - E_j \right) \Big/ VAN_j = CD_j \Big/ VAN_j$$

where: CD_j = domestic opportunity cost of the resources used in j; and VAN = net foreign exchange earned or value added to international prices.

[17] The shadow exchange rate represents the average cost to the economy to produce one additional unit of foreign exchange.

[18] The products that are most difficult to classify are those used as raw materials in different industrial processes. Some products, such as cotton, are especially difficult because they are used in several processes (cotton is used in textiles and cottonseed cake); in such cases, one would have to choose the processes that occupy the most important place in family spending and on the basis of this percentage, estimate cotton's share in this spending.

	1	0_1
	Milk (5.94) Bread (wheat) (3.27) Maize (1.49) Barley Quadrant II	Beef cattle (9.86) Potatoes (4.55) Rice (3.57) Vegetable oil (soy, palm, cottonseed, sesame (3.05) Sugar loaf (2.01) Eggs (1.80) Cocoa (1.71) Quadrant I
1.5		
	Fruit (1.21) Pasta (wheat) (1.09) Beans and lentils (0.80) Peas (0.80) Plantain (0.74) Cassava (0.61) Oats (0.25) Quadrant III	Cotton Bananas (1.24) Coffee (1.19) Sugar (1.01) Tobacco Flowers Quadrant IV
0_2		

Fig. 2. Priorities of products using socioeconomic criteria. Point 0_1 represents the origin for comparative advantage or the quotient between the domestic cost of resources and the shadow exchange rate; point 0_2 represents the origin for the product's participation in family spending and is measured vertically. This participation or share of spending is shown in parentheses and represents the structure of spending for blue-collar workers in the city of Bogota. Comparative advantages are positioned subjectively and will remain so until the corresponding calculations have been made. Another way of situating along the vertical axis would use the quotient domestic production and consumption with a dividing line at point 1. This line would be the "line of self-sufficiency." In this case, point 0_2 will be at the top corner of the matrix.

cides to adopt a policy of promoting exports and obtaining foreign exchange to provide guaranteed supplies of food, quadrant IV would be favoured. However, if the government adopts a food self-sufficiency policy, quadrant II is favoured. Exporting countries adopting the first type of policy would prefer quadrants I and IV, whereas self-sufficient countries would choose quadrants I and II.

Furthermore, the products that should receive priority government financing and those that should be left to the initiative of the private sector must also be determined. This is done by examining the price elasticity of demand. When the demand for a product is inelastic, consumers reap the benefits of research; when demand is elastic, producers benefit from research. Therefore, the government should finance research on priority products having the least price elasticity of demand and continue up the scale until available resources are exhausted. Research on other products should be financed by the private sector. Because exportable products usually have high price elasticity of demand, the products in quadrant IV would be financed by the private sector (coffee, sugarcane, cotton, etc.), whereas the government should handle the products in quadrants I and II. In Colombia, the choice of the products in quadrants I and IV would give products from the tropical zone a clear advantage over those from the Andean zone (except for coffee). Having set product priorities at the economic level, technological and research priorities must now be established.

Identification of Socioeconomic Priorities in Terms of the Internal and External Market for Agricultural Production

The Concept of Total Value of Agricultural Circulation

Among the main functions assigned to the agricultural sector in the economic development process, two aspects are of particular importance: the satisfaction of the internal demand for food and raw materials needed in the industrial sector (production for the internal market); and the generation of foreign exchange needed to sustain the development of the national production system, both through agricultural exports and through the substitution of agricultural imports (exports and imports). These two aspects are of central importance to some of the other functions assigned to this sector, such as the broadening of the domestic market for goods and services produced in other sectors of the economy, and the liberation of part of the labour force to work in nonagricultural activities.

The capacity of the agricultural sector to carry out these functions depends, to a large extent, on the magnitude of the gross agricultural product generated by the sector. It is for this reason that one of the most common indicators to measure the relative importance of each agricultural product, in terms of the function it performs within the whole economy, has been the participation of that product in the total value of agricultural production.

In order to take into consideration the different functions that have been assigned to the agricultural sector, a more appropriate indicator appears to be the total value generated by the circulation of agricultural products in a given economy, which will be referred to as the total value of agricultural circulation.

The value generated by the circulation of agricultural products has three major components or sources: agricultural production for the internal market (APIM); agricultural exports (X); and agricultural imports (M). The total value of agricultural circulation (AC) is defined as the sum of the value generated by these three components, i.e., AC = APIM + X + M. This indicator, which is somewhat different from that of the total value of agricultural production, takes into consideration the three dimensions that were identified with respect to the main functions assigned to the agricultural sector in the process of economic development, i.e., production for the internal market (satisfaction of the demand for food and raw materials), agricultural exports, and agricultural imports.[19] Table 11 shows the total value of agricultural circulation in Colombia from 1972–1976, as well as the annual value of its three components (in constant values of 1970).

A Model for the Identification of Product Priorities: Participation in the Total Value of Agricultural Circulation

The basic premise of this model is that the relative importance of every agricultural product, in terms of the function it performs within the whole economy, can be established on the basis of the participation of that product in the total value of agricultural circulation. A "general priority index" for each crop or agricultural product can be computed through the following procedure:

(1) The first step is to determine the total value of agricultural circulation in the country during a given time period. This entails: (a) Disaggregation of the total value of agricultural production into its two major components, production for the internal market and agricultural exports. The value of production for the internal market is estimated on the basis of producer's prices; production for agricultural exports is established by converting the FOB value of exports into local currency. (b) The value of agricultural imports (at CIF prices) is converted into local currency.

(2) The relative importance of these three components is established in terms of their percentage participation in the total value of agricultural circulation. This is done not only on the basis of a single year, but on the basis of the average annual value over a number of years, in order to avoid distortions of exceptional exports or imports in any given year. Thus, Table 11 indicates the annual values of these three components in Colombia from 1972–1976, as well as the average annual value of them for this time period. This last information indicates that in Colombia, production for the internal market represents 71.6% of the total value of agricultural circulation, whereas exports represent 25.3% and imports constitute only 3.1% of the total value. These three percentages are used as "weighting coefficients or parameters" in a subsequent step of this method.

(3) The percentage participation of each crop or agricultural product in the three components under analysis is determined. This provides information with respect to the relative importance of each product in agricultural production for the internal market, agricultural exports, and agricultural imports. Information related to Colombia is given in Tables 12, 13 and 14 for the 1972–1976 period.

(4) The "general priority index" for each crop or agricultural product can be computed as follows: (a) The percentage participation of each crop making up the three components of agricultural circulation is multiplied by the relative importance or weight of the respective component in the total value of agricultural circulation. This weighting procedure, which uses the coefficients determined in the second step, provides the "weighted participation" of the different crops in the three components of agricultural circulation. (b) The "general priority index" for each crop is computed by adding the "weighted coefficients of participation" of that crop in the three components under analysis. It should be noted that normally any given crop appears in two of the three components, because it is only under very special circumstances that the same crop is both exported and imported in a specific country.

The procedure can be better understood through an example. As seen in Table 15, the percentage participation of coffee in the components of agricultural circulation in Colombia is: in production for the domestic market, 5%; in exports, 73.3%; in imports, 0%. Because the relative weight of each of these components in the Colombian case is 71.6%, 25.3%, and 3.1%, respectively, the weighting procedure described above and the general priority index of coffee in this country is:

	Participation (%)	Weighting coefficient	Weighted participation
Internal market	5.0	71.6	3.58
Exports	73.3	25.3	18.54
Imports	0.0	3.1	0.00
General priority index			22.12

Quantitative indicators of relative priorities can be effectively used as one of the main criteria in the final decision-making process for resource allocation but they should not be considered as the only criteria. At least two other aspects should be taken into consideration. In the first place, as a result of a

[19] The total value of agricultural production only reflects the first two components.

political decision, and aside from any considerations on social returns, it could be decided to stimulate certain products as part of a national policy of guaranteeing the internal supply of those food crops or raw materials. Secondly, an analysis of past production trends and the future outlook for certain crops may identify agricultural products of potential importance to the country, although specific crops may not be of major importance in terms of present levels of production. This may be the case for some minor or nontraditional crops in any given country. Thus, the priorities established should be partially modified or adjusted in the final decision-making process. Nevertheless, this does not invalidate the indicators and procedure that have been presented because they provide a clear basis for decision-making in the process of resource allocation for agricultural research.

It should also be pointed out that in the application of this model in Colombia, two additional variables or indicators were taken into account to see if the model gained in analytical power by substantially modifying the priorities initially identified. These additional variables were rural employment generated by each crop and the extension of land (area) under that crop's production. No significant modification was introduced by these variables in the priority ranking established on the basis of the indicators that have been suggested.

A final methodological note is in order with respect to the choice of shadow prices versus market prices in analyzing the three components of the total value of agricultural circulation. In the application of this model in Colombia, market prices were chosen for two reasons. Firstly, the price of most agricultural products in Colombia is not substantially distorted by political and institutional actions; thus, the difference between market prices and shadow prices is not considered to be significant. If this were not the case, the use of shadow prices might be advisable. Secondly, due to the operational (data gathering) and conceptual difficulties related to the use of shadow prices, it was felt that the additional precision to be gained by their use (in terms of a different and better priority ranking) would be so marginal that it would not compensate for the additional effort required in data gathering and processing.

One of the greatest operational advantages of the model presented is that the data it requires are readily available in any country and the application of the data entails no great difficulty. The observations made earlier, however, regarding the need to adjust the priority ranking established by the indicators that have been suggested, on the basis of political considerations or trend analysis, should be kept in mind.

Application of the Model to Colombia

This method for identifying product priorities for research purposes was applied to the 28 agricultural products that constitute most of the agricultural production in Colombia. Between 1972 and 1976 the annual average of the total value of agricultural circulation generated by this sector in Colombia was $47 139.3 million Colombian pesos (expressed in constant 1970 pesos). Of this total, production for the internal market represents 71.6%; agricultural exports represent 25.3%; and agricultural imports constitute the other 3.1% (Table 11). The annual average values over a number of years were used to avoid distortions that could be introduced by exceptional agricultural exports or imports in any given year.

Following the methodology previously described, the percentage participation of each crop or agricultural product in the three components of the total value of agricultural circulation was determined. Table 12 shows the percentage participation of the main agricultural products of the country in agricultural production for the internal market (1972–1976); Tables 13 and 14 show the relevant participation coefficients of these same products with respect to the value of agricultural exports (1972–1978) and imports (1972–1977) respectively. As in the previous case, an average annual participation rate of the different products, during a given time period, was computed in order to avoid the distortions that could be introduced by exceptionally high or low crops of a specific product in any given year.

On the basis of the information provided in Tables 11–14, the weighted participation coefficient and general priority index of each product were computed. The weighted participation coefficients of the main agricultural products of Colombia are shown in Table 15, as well as the general priority index of each product. This index measures the relative importance (or participation) of each product in the total value of agricultural circulation in the country during the time period being analyzed (1972–1976). The initial participation rates appearing in Table 15 are really average annual participation rates for this period, derived from Tables 12, 13, and 14.

For comparative purposes, Table 15 also includes information regarding the participation rates of the different crops and products in the total value of agricultural production for this same period. By comparing this with the general priority index, one can compare the priority rankings that are established by using participation rates in the total value

Table 11. Total value and structure of agricultural circulation, 1972–1976 (millions of constant 1970 pesos).

	1972	1973	1974	1975	1976	Average value	Weighting coefficients
Value of production for the internal market	31186.1	32047.5	34908.0	36472.2	34276.5	33778.1	71.6
Value of exports	10293.7	11947.4	11404.8	13467.5	12489.4	11920.6	25.3
Value of imports	741.1	1332.9	1906.1	1183.0	2040.6	1440.7	3.1
Total value of agricultural circulation	42220.9	45327.8	48218.9	51122.7	48806.5	47139.4	100.0

Source: Balcazar, Alvaro and Torres, Ricardo. 1981. Selección de prioridades socio-económicas para la investigación agropecuaria. COLCIENCIAS, p. 79.

Table 12. Percentage participation of main products in agricultural production for the internal market, 1972–1976.

Product	1972	1973	1974	1975	1976	Average
Coffee	5.4	5.0	4.9	3.8	5.7	5.0
Rice	4.8	7.7	8.3	7.0	6.1	6.8
Barley	0.5	0.5	0.5	0.8	0.4	0.5
Maize	4.5	5.0	3.9	3.4	4.3	4.2
Sorghum	1.1	1.6	1.6	1.4	1.7	1.5
Wheat	0.4	0.4	0.4	0.3	0.3	0.4
Potato	3.0	3.3	3.3	6.1	4.4	4.0
Plantain	4.9	4.6	4.7	5.9	6.1	5.2
Cassava	7.5	5.4	6.7	7.6	6.1	6.7
Yam	—	0.4	0.3	0.3	0.3	0.3
Sugarcane	3.2	2.9	2.6	2.4	4.4	3.1
"Panela"[a]	5.1	5.7	3.7	3.1	7.6	5.0
Soybean	0.8	0.8	1.0	1.4	0.6	0.9
African Palm	—	0.8	1.1	0.7	0.7	0.8
Sesame	0.4	0.2	0.3	0.3	0.3	0.3
Cotton	4.7	5.3	5.4	4.0	6.2	5.1
Cocoa	0.7	0.8	0.8	0.7	0.9	0.8
Tobacco	0.5	0.7	0.5	1.1	0.5	0.7
Beans	1.1	0.9	1.1	1.7	1.1	1.2
Bananas	1.0	1.4	1.2	1.0	1.6	1.2
Livestock						
Dairy	15.4	9.7	9.5	7.4	—	10.5
Beef	—	19.0	16.8	11.8	14.3	15.5
Pigs	5.7	7.2	4.9	6.4	—	6.0
Sheep	0.1	0.1	0.1	0.1	0.1	0.1
Poultry						
Meat	4.4	4.9	5.2	5.7	—	5.0
Eggs	4.7	5.3	4.8	4.3	4.5	4.7
Others	20.1[b]	0.4	6.4	11.3	21.8[b]	12.0

[a] Sugar loaf.

[b] The high unexplained percentages in these 2 years are due to the lack of information, in those particular years, for one or two important products.

Source: Balcazar, Alvaro and Torres, Ricardo. 1981. Selección de prioridades socio-económicas para la investigación agropecuaria. COLCIENCIAS, p. 75.

of agricultural production and participation rates in the total value of agricultural circulation. The difference between these two priority rankings is greater in those countries or products where agricultural imports play a more important role.[20] Thus, the difference is greater in products such as wheat in the Colombian case, due to the significant import component for this crop.

[20] The overall importance of agricultural imports in Colombia is not very significant, representing only 3.1% of the total value of agricultural circulation.

Table 13. Percentage participation of main products in the value of agricultural exports in Colombia, 1972–1978.

Product	1972	1973	1974	1975	1976	1977	1978	Average
Coffee	72.9	77.4	73.1	65.7	77.5	81.8	83.0	73.3
Bananas	2.3	2.0	3.0	3.1	3.7	2.5	3.1	2.8
Sugar	4.9	3.9	8.5	9.3	2.2	0.1	0.9	5.8
Cotton	8.7	4.3	5.6	7.4	5.3	6.3	3.0	6.2
Tobacco	1.7	2.0	2.1	1.2	2.3	1.1	1.1	1.9
Rice	0.1	0.1	—	2.0	1.9	1.1	1.1	0.8
Potatoes	—	—	—	0.2	0.1	0.1	0.1	—
Cocoa	—	—	—	—	—	—	—	—
Maize	—	—	—	0.2	—	—	—	—
Beans	0.3	0.3	1.0	0.8	0.5	0.5	—	0.6
Vegetables and legumes	—	—	—	—	—	—	—	—
Tomatoes	—	—	—	—	—	—	—	—
Soybeans	0.1	0.1	—	—	—	—	—	—
Oats	—	—	—	—	—	—	—	—
Flowers	0.5	1.1	1.9	1.9	2.0	1.8	2.2	1.5
Bovine stock	2.3	0.3	0.3	2.6	1.3	0.6	0.6	1.3
Beef cattle	4.1	5.2	3.8	2.2	1.8	1.3	2.0	3.4
Others	2.1	3.3	0.7	3.4	1.4	2.8	2.9	2.4

Source: Balcazar, Alvaro and Torres, Ricardo. 1981. Selección de prioridades socio-económicas para la investigación agropecuaria. COLCIENCIAS, p. 68.

Table 14. Percentage participation of main products in the value of agricultural imports, 1972–1977.

Product	1972	1973	1974	1975	1976	1977	Average 1972–76
Wheat	67.1	39.4	55.5	60.0	38.0	15.6	52.0
Maize	0.2	11.6	4.3	—	1.3	7.8	3.5
Beans	0.5	0.2	0.2	0.3	—	1.0	0.2
Barley	—	7.5	5.2	2.7	5.7	8.7	4.2
Soybean	2.9	7.4	6.4	—	—	—	3.3
Soybean oil	0.2	1.0	3.4	2.4	8.4	13.4	3.1
Peas	0.1	1.0	1.2	3.0	1.2	3.2	1.3
Chick-pea	0.4	2.8	1.0	—	0.3	0.5	0.9
Lentils	1.8	3.8	3.9	3.4	3.7	3.6	3.3
Apples	5.5	1.8	2.2	3.4	2.8	2.1	3.1
Oats	3.5	2.5	2.0	2.6	1.6	1.6	2.4
Cocoa	12.0	8.8	7.1	6.5	0.3	—	6.9
Beef cattle	0.1	0.1	0.2	0.2	0.2	0.5	0.1
Dairy cattle	1.9	1.5	1.4	1.8	4.8	12.0	2.3
Poultry	1.2	0.8	0.5	0.8	0.6	0.6	0.8
Eggs	0.1	—	—	—	—	—	—
Others	2.5	9.8	5.5	12.9	31.1	29.4	12.4

Source: Balcazar, Alvaro and Torres, Ricardo. 1981. Selección de prioridades socio-económicas para la investigactión agropecuaria. COLCIENCIAS, p. 73.

In addition to establishing a rank order among the 28 agricultural products being considered, the priority index can be used to identify clusters or groups of products upon which it is possible to classify the different products in terms of general priority levels: high, medium, and low priority. An analysis of the index in Table 15 identifies four groups of products:[21] group 1 (index value >7): coffee, beef

[21] The index values related to the four groups do not represent absolute cutting points in this scale. The groups were established more on the basis of the clustering of products and on the distances or differences that appear between them.

Table 15. Weighted participation coefficients of main products in total value of agricultural circulation and computation of general priority index.

Product	Participation in total agricultural production value, 1972–76	Participation in			Weighted participation in			General priority index
		Domestic market (%)	Exports (%)	Imports (%)	Domestic market (%)	Exports (%)	Imports (%)	
Group 1								
Coffee	15.8	5.0	73.3	—	3.58	18.54	—	22.12
Beef cattle[a]	13.9	15.5	4.7	0.1	11.10	1.19	—	12.29
Dairy cattle	8.9	10.5	—	2.3	7.52	—	0.07	7.59
Group 2								
Cotton	4.9	5.1	6.2	—	3.65	1.57	—	5.22
Rice	5.9	6.8	0.8	—	4.87	0.20	—	5.07
Cassava	5.7	6.7	—	—	4.80	—	—	4.80
Pigs	5.1	6.0	—	—	4.30	—	—	4.30
Group 3								
Plantain	4.5	5.2	—	—	3.72	—	—	3.72
Sugarcane	3.2	3.1	5.8	—	2.22	1.47	—	3.69
Poultry meat	4.3	5.0	—	0.8	3.58	—	0.02	3.60
"Panela" (sugar loaf)	4.3	5.0	—	—	3.58	—	—	3.58
Eggs	4.0	4.7	—	—	3.36	—	—	3.36
Maize	3.6	4.2	—	3.5	3.01	—	0.11	3.12
Potato	3.5	4.0	—	—	2.86	—	—	2.86
Group 4								
Wheat	0.3	0.4	—	52.0	0.29	—	1.61	1.90
Bananas	1.9	1.2	2.8	—	0.86	0.71	—	1.57
Sorghum	1.3	1.5	—	—	1.07	—	—	1.07
Beans	1.2	1.2	0.6	0.2	0.86	0.15	—	1.01
Tobacco	0.9	0.7	1.9	—	0.50	0.48	—	0.98
Soybean	0.8	0.9	—	6.4[b]	0.64	—	0.20	0.84
Cocoa	0.7	0.8	—	6.9	0.57	—	0.21	0.78
African Palm	0.7	0.8	—	—	0.57	—	—	0.57
Barley	0.5	0.5	—	4.2	0.36	—	0.13	0.49
Yam	0.3	0.3	—	—	0.21	—	—	0.21
Sesame	0.2	0.3	—	—	0.21	—	—	0.21
Oats	—	—	—	2.4	—	—	0.07	0.07
Sheep	—	0.1	—	—	0.07	—	—	0.07
Relative importance of components of agricultural circulation		71.6	25.3	3.1				

[a] Includes live bovines.
[b] Includes soybean oil.
Source: Derived from Tables 12, 13, and 14.

cattle, and dairy cattle; group 2 (index value 4–7): cotton, rice, cassava, and swine production; group 3 (index value 2–4): plantain, sugarcane, poultry, "panela" (sugar loaf), eggs, maize, and potatoes; and group 4 (index value < 2): wheat, bananas, sorghum, beans, tobacco, soybean, cocoa, African palm, barley, yam, sesame, oats, sheep, and peanuts. Groups 1 and 2 are considered to be high priority for the country on the basis of their relative importance in the total value of agricultural circulation. Groups 3 and 4 represent medium and low priority products respectively.

Most of the products in groups 1–3 are food crops for direct consumption; cotton and sugarcane are used as raw materials for the manufacturing industry and coffee is intended primarily for export. Most of the foreign exchange produced by the export of agricultural products comes from crops in the first three priority groups.

Because the variables used in this model are basically production variables (i.e., production for the internal market, agricultural exports, and agricultural imports), two additional indicators were taken into account to see if they improved the analytical power of the model by substantially modifying the priority ranking established by the initial set of variables. The two additional variables considered were rural employment generated by each crop and the extension of land (area) under that crop's production.[22]

Table 16 compares the participation rates of the different crops in the total value of agricultural circulation (general priority index) with their relative importance in terms of the other two variables. Very few agricultural products undergo a change in their priority ranking important enough to warrant a reclassification in terms of general priority levels. As indicated in Table 16, only three products (plantain, maize, and "panela") shift from medium priority (group 3) to high priority (groups 1 and 2). Plantain and maize increase substantially in terms of both additional variables. The importance of "panela" (sugar loaf) is enhanced mainly by the employment it generates in the agricultural sector. The high ranking of maize in terms of the area under production should be interpreted with some reservation because the greater part of this area is shared with other crops (multiple cropping systems). Thus, the net area actually used for maize would be much smaller.

The importance of tobacco increases to some extent in terms of employment generated (from low to medium), but it consistently ranks low in terms of the other two indicators. Thus, it would still remain as low priority.

The preceding analysis clearly shows that only minor modifications in the general priority ranking are introduced by the two additional variables. The overall ordering of products is maintained to a large extent.

Identification of Research Priorities within Selected Products or Problem Areas

The process for the identification of research priorities within selected products or problem areas was designed and carried out by the Instituto Colombiano Agropecuario (ICA) in 1979 and 1980. The first version of the National Plan for Agricultural Research (Plan Nacional de Investigación Agropecuaria) was published by ICA in January of 1981. A more detailed description and analysis of the methodology that was used in this process is presently being prepared by ICA.

Main Steps Followed in the Process of Identifying Research Priorities within Products: A Matrix Approach

As mentioned earlier, despite the fact that the formal identification of product or problem priorities had not been completed, the decision was taken in Colombia to go ahead with the determination of technological requirements and research needs at the product level.

In order to carry out this second phase of the planning process, the list of 28 agricultural products compiled by the Ministry of Agriculture (OPSA) was taken as a point of reference. Because these 28 products represent almost all of the agricultural production for which there is information, the proposed research programs cover a wide range of the present agricultural production.[23]

The process of identifying research priorities at the product level was carried out in four steps: (1) regionalization of the country into "ecologically homogeneous zones"; (2) characterization of each

[22] Rural employment generation is measured by multiplying the number of hectares under a given crop's production by the number of man-days of labour required per hectare. These are estimates published by the Ministry of Agriculture.

[23] The only major exceptions are coffee and sugarcane, which in the case of Colombia are research areas that are in the hands of the private sector.

Table 16. Comparison of the general priority index based on agricultural circulation with participation in area under agricultural production and employment generation.

Product	General priority index based on agricultural circulation	Participation in area under agricultural production	Participation in employment generated by agricultural sector
Group 1			
Coffee	22.12	26.6	17.2
Beef cattle	12.29	[a]	—
Dairy cattle	7.59	[a]	—
Group 2			
Cotton	5.22	7.0	7.3
Rice	5.07	9.6	5.9
Cassava	4.80	5.8	10.2
Pigs	4.30	—	—
Group 3			
Plantain	3.72	9.5	9.9
Sugarcane	3.69	2.1	2.9
Poultry	3.60	—	—
"Panela" (sugar loaf)	3.58	4.6	9.6
Eggs	3.36	—	—
Maize	3.12	15.6	12.2
Potatoes	2.86	3.3	6.4
Group 4			
Wheat	1.90	0.8	0.4
Bananas	1.57	0.5	1.5
Sorghum	1.07	4.7	0.8
Beans	1.01	2.8	2.2
Tobacco	0.98	0.8	7.1
Soybean	0.84	1.6	0.8
Cocoa	0.78	1.5	3.2
African Palm	0.57	0.5	0.9
Barley	0.49	1.7	0.3
Yam	0.21	0.3	0.7
Sesame	0.21	0.8	0.4
Oats	0.07	—	—
Sheep	0.07	—	—
Peanuts	—	0.1	—

[a] Livestock occupies approximately 25 million hectares, which implies that it would still remain in this high priority category in terms of the area under cattle production. Because it is so extensive in land use, this figure was not included for the determination of these percentages as it would drastically distort the overall picture.

Source: Balcazar, Alvaro and Torres, Ricardo. 1981. Selección de prioridades socio-económicas para la investigactión agropecuaria. COLCIENCIAS.

region and analysis of the principal production systems that are found in them; (3) identification and analysis of the main "technological constraints" that have a negative impact on the production or productivity levels of the different products, under the specific environmental conditions that characterize each region; thus making the analysis both product-specific and region-specific; and (4) identification and analysis of potential research topics or issues that are considered to be important to solve the technological constraints faced by each product in specific regions.

The first three steps were carried out through a national survey, on the basis of which a technological profile or technological diagnosis of the agricultural sector was formulated.[24] The fourth step was carried out through working groups established for each product, in which the delphic technique was used (group discussions) for the identification and analysis of research topics or issues in response to the technological constraints previously identified.

In the first phase of the analysis, the country was divided into "natural regions" and "ecologically homogeneous zones," mainly on the basis of physical parameters that characterize and differentiate each zone. The principal physical parameters

[24] See ICA. 1980. Sector agropecuario Colombiano: diagnóstico tecnológico. Two volumes.

used in regionalizing the country were: climatic variables, water availability (hydrological resources), types of soil and soil characteristics, and dominant flora and fauna.

Seven main "natural regions" were identified within the country: Caribbean Region, Pacific Region, Andean Region, Inter-Andean Valleys, Orinoquia Region, Amazon Region, and Island Territories. Within each, an effort was made to identify subregions that could define ecologically homogeneous zones of economic importance (where relevant and only for the purpose of a more detailed analysis). These are geographical units that are more homogeneous from the point of view of the abovementioned parameters.

The second and longest phase of this analysis was the characterization of these natural regions or ecologically homogeneous zones. This characterization covered several aspects:

(1) Characterization of the physical or environmental parameters, for example, climatic characteristics were analyzed in terms of: total and monthly precipitation levels (rain), temperature range and monthly variations, relative humidity, and sunshine. The soil characteristics were analyzed in terms of the dominant types of soil and in terms of such parameters as erosion, depth, external drainage, fertility (i.e., pH values), salinity, and elements that are low or in excess in the types of soil found in that region. The other aspects are characterized by similar parameters that are relevant for each case.

(2) Characterization of the socioeconomic characteristics of the region. Both economic and social aspects of the agricultural sector in the region were analyzed, such as: agricultural and animal production (both in terms of volume and in terms of its participation in national production); regional consumption and regional contribution to the national internal market and to exports; importance of agricultural production in the regional economy; economically active population, rural employment, and migration; land tenure structure and relationship with cropping and farming systems; and organizations of producers and managerial capacities.

(3) Characterization of the agricultural production system in that region. Identification and analysis of the principal agricultural products (both in terms of crops and animal production) and the principal farming systems and cropping systems that are being used. This leads to an analysis of the interaction between crops, cropping systems, and the environmental and socioeconomic characteristics of the region. Other aspects, such as the degree of mechanization, use of agricultural inputs, labour or capital intensity, productivity levels of the different crops or animals, energy sources, and forms and timing of planting and harvesting activities, are also taken into consideration in order to characterize the type of production technologies utilized.

(4) Characterization of the support services that exist in the region. This refers to such services as technical assistance, credit facilities, commercialization mechanisms, supply of agricultural inputs, transportation facilities, training institutions, and other support services.

The third step plays a central role in the process of identifying product research priorities because it is related to the identification and analysis of the main "technological constraints" that have a negative impact on the production or productivity levels of the different products under consideration. In order to do this, it was necessary to identify the principal technological factors that intervene in the production process, both in the case of crops and animal production.

In the case of crops, the principal technological factors were conceived in terms of eight categories, each one related to a specific discipline of the agronomical sciences. The eight technological factors are: (1) farming practices (including cropping systems); (2) production equipment: agricultural machinery and implements; (3) knowledge of plant genetics and the development of desirable genotypes and their seeds; (4) knowledge of insects, rodents, and molluscs, their impact on crops, and control methods; (5) knowledge of plant diseases, disease-causing agents (bacteria, virus, fungi), and control methods; (6) knowledge of plant physiology in order to improve their efficiency (yield) or control them (weeds); (7) soil as a factor of production; knowledge of soils: their characteristics, improvement, and conservation; and (8) water as a factor of production; knowledge of hydrological resources and water management and distribution (irrigation).

In the case of animal production, the following six technological factors were considered: (1) knowledge of animal production systems and techniques; (2) knowledge of animal physiology and reproduction; (3) knowledge of animal genetics and crossbreeding; (4) animal food and feeding systems; nutrition problems; (5) pasture and forage as a factor of production; (6) knowledge of animal diseases, their causes, and control.

In each region, an effort was made to identify and analyze the main "technological constraints" that have a negative impact on the production or productivity levels of the principal products (crops and animals) under the specific environmental conditions that characterize that region. These technological constraints were identified by analyzing the situation of each technological factor (either for crops or animals), as well as the impact of specific problems or bottlenecks identified in them on production or productivity levels. Thus, technological constraints were expressed in terms of limitations, deficiencies, or problems related to one of the technological factors that was responsible for low production or productivity levels (i.e., certain crops in a given ecological region or zone might be facing soil deficiency problems, or might show low yields or high vulnerability to diseases; or an important bottleneck for animal production in certain regions might be found to be poor pastures or inefficient animal production systems). These technological constraints lead to the identification of research needs and specific technological requirements (such as technical assistance) at the level of each product in given geographical regions (ecological zones) of the country.

These steps define an analytical matrix that permits different agricultural products to be related to specific technological constraints under certain environmental conditions that define ecologically homogeneous zones (Fig. 3). Each cell of the matrix in Fig. 3 defines a potential research area or topic, in order to solve a specific technological constraint (production problem) that is limiting the productivity level of a given agricultural product, within an identifiable region or ecological zone.

The same product may face different technological constraints, in different geographical or ecological regions. For example, in a given region the crop under consideration may face a serious problem of soil deficiency, whereas in other regions the main problem may be high vulnerability to diseases, despite relatively good soils. Furthermore, the importance of a given technological constraint may vary from one region to another for the same agricultural product. Thus, the analysis of technological constraints is both product-specific and region-specific, although some of them may cut across several regions.

It should also be noted that not all cells of the matrix are relevant, because not all products are found in all ecological regions or because a given technological constraint may not be relevant or important for all agricultural products (Fig. 3). The importance of each matrix cell (research topic) depends upon both the relative importance of the product and the magnitude (difficulty) and importance of the technological constraint to be solved.

The main output of the first three steps in the process of defining research priorities at the product level is the identification and description (diagnosis) of important technological constraints that limit production or productivity levels of specific agricultural products in certain ecological regions.[25] Further analysis of the importance of each research area (cell of the matrix), as well as the disaggregation of each area into more specific research topics (potential research projects), was carried out in the fourth step of the process.

Use of the Delphic Technique for the Identification of Technological Requirements and Research Needs

Having determined the principal technological constraints that limit the production or productivity levels of specific crops in certain ecological regions, the next step of the process was to establish research needs (and, therefore, research priorities). This implies a disaggregation of each of the matrix cells in Fig. 3 into research topics or projects that may contribute to the solution of each technological constraint.

To do this, special working groups were established in the different product and problem areas that were being considered. Each working group was made up of a group of experts with extensive experience in specific products and research areas, and with a good knowledge of the agricultural sector in the country and the production problems it faces.

These groups used the "Delphic" technique, which involved a group or panel discussion on the technological constraints under consideration, for the purpose of arriving at a consensus on the different aspects involved in each technological bottleneck and the research topics or projects that could contribute to the solution of those problems. This technique has been used widely in many countries, both in the identification of research needs and priorities, and in technological assessment (analysis of future technological developments and their impact).[26]

In this analysis, each group took into consideration the three major aspects that were identified in Fig. 1 as components of the general methodological framework for the identification of research priorities: (1) the technological constraints that have a negative impact on the production or productivity levels of specific agricultural products under the environmental conditions that characterize a given

[25] In the Colombian case this is presented in ICA. 1980. Sector agropecuario Colombiano: diagnóstico tecnológico. Two volumes.

[26] For a discussion of the use of the Delphi methodology and of matrix techniques in this type of analysis, see Cetron, M.J. and Bartocha, B. 1972. The methodology of technology assessment. New York, New York, Gordon and Breach Science Publishers.

Principal products considered to be of high socioeconomic importance or priority for the country	Principal technological constraints and ecologically homogeneous zones									
	Technological constraint 1			Technological constraint 2			Etc.	Technological constraint *i*		
	EHZ-1	EHZ-2	EHZ-*i*	EHZ-1	EHZ-2	EHZ-*i*		EHZ-1	EHZ-2	EHZ-*i*
Product 1										
Product 2					α / β					
Etc.										
Product *i*										

Fig. 3. Matrix approach to research planning in agricultural research. EHZ refers to the different ecologically homogeneous zones. α represents the importance of a given technological constraint. for a specific agricultural product, in a specified ecological zone or region. β represents the importance of the existing pool of knowledge and technological know-how that may be used in the solution of a specific technological constraint.

geographical region (demand for technology); (2) the pool of existing knowledge, know-how, and technologies (within the country or abroad) that is already available and that could be used to solve a specific technological constraint (supply of technology); (3) the desirable characteristics of technological change that one wishes to promote in the agricultural sector (desirable technological path); this provides criteria that may be used to evaluate technological alternatives, when they exist, or to design new technologies through research efforts.

The importance of the second factor is quite evident. In some cases, a technological constraint may be identified in a given product, despite the fact that there is technological know-how already available that could be used to solve the production problem under consideration. In such a case, the problem is one of transfer of technology to the producer and not of development of new technologies through research programs.

Each group, whose attention always centred on a specific product, had at its disposal three main inputs as a starting point for their deliberations:

(1) The technological diagnosis of the agricultural sector analyzes the production problems of the different crops, identifies major technological constraints, and makes a preliminary evaluation of the importance of each constraint.

(2) Brief state-of-the-art reports were prepared for each product (and, thus, for each group), summarizing the present research effort and the principal available technologies developed for that product. The objective of these reports was to have an approximate idea of the pool of existing know-how and technologies related to the product under consideration.

(3) The knowledge and experience each participant brought to the group. Given the importance of this factor, the selection of the group members is of crucial importance in this Delphi methodology.

The discussions of the working groups centred around two main issues: (1) analysis of the real importance and nature of each of the technological constraints that are confronted (each relevant matrix cell in Fig. 3) and (2) identification of research projects that should be carried out in order to generate the knowledge or know-how that is needed for the solution, elimination, or drastic reduction of that technological constraint.

With respect to the first issue, the importance and nature of the technological constraint under consideration was analyzed by comparing two indicators: the importance of the technological constraint that is being faced, from the point of view of its impact on production or productivity levels (α) and the importance or amount of the existing know-how that could be used effectively to solve or reduce the technological constraint (β).

The magnitude of these two indicators was "measured" in terms of an integral scale ranging in value from 1–10. In this scale, 1 represents a technological constraint of very low importance (impact), and a very low or limited technology supply. Ten represents a very important technological constraint (strong impact), and a highly important supply of technology that could be used to control or diminish the technological constraint under consideration. In both instances, 5 represents an intermediate situation. The values given to each technological constraint, with respect to these two indicators, were determined by each group on the basis of the three sources of information available to them. In terms of the analytical matrix presented in Fig. 3, every relevant matrix cell (each technological constraint identified) has these two values.

The range of points in both scales was divided into three categories: 1–3, low; 4–6, medium; 7–10, high. These three categories were used in the subsequent applications of the two indicators.

The comparison between the two indicators (α/β) in the case of each technological constraint was used to determine the importance or priority of that constraint, as well as some indication as to the nature of the technological problem faced. The different possible combinations of the comparison between the two indicators (α/β) were used to classify all identified technological constraints into three levels of priority (high, medium, and low), according to the relationship between the perceived importance of the technological constraint (α) and the present availability (supply) of know-how and technologies that could be used to control or diminish that constraint (β). The different possible combinations of this relationship (α/β) and their interpretation for assigning an overall level of priority to each technological constraint (matrix cell) are: high priority: medium/low, high/low, high/medium; medium priority: low/low, medium/medium, high/high; low priority: low/medium, low/high, medium/high.

An effort to formulate research needs and projects (the next step of the process) was carried out only for those technological constraints with high and medium priority levels. Low priority technological constraints were disregarded, except in those cases where a certain ongoing research level was considered necessary to maintain a technology previously developed.

In certain cases, an analysis of the relationship between α/β gives some insight into the nature of the technological problem that is being confronted. In the case of an important technological constraint, with a low availability or supply of technological know-how to cope with the problem, there is obviously a need for a research effort to develop the necessary technology. In the case of an important technological constraint (i.e., seriously limiting production or productivity levels) and the existence or availability of an important (high) or moderately important (medium) body of knowledge or usable technology to solve that constraint, the technological problem confronted is *not*, basically, a research problem (lack of knowledge).

In such a situation, the technologies that have been developed in the agricultural research stations (within the country or abroad) are not being used by the producers. Two major factors can explain this situation. Firstly, this may reflect a problem of inefficient agricultural extension and technology transfer to the producer. Thus, the technological requirement generated in this situation is not for more research but for better technology transfer mechanisms (technical assistance, credit, etc.).

Secondly, this situation may also be partly due to the fact that the technology that has been developed (existing supply) is not the most appropriate one for the type or characteristics of the producers for which it was developed. For example, the cost of the agricultural input (i.e., fertilizers) necessary to use that technology may be too high for the type of producer that should be using it, or the degree of mechanization or scale of production that are required do not correspond to the characteristics or capacity of the latter. In such a case, the conditions and characteristics of the producers themselves would require modification or alternative technologies more adapted to the production conditions existing in the country (research requirement) would have to be developed.

These two examples show that an analysis of the relationship α/β for each technological constraint may provide important insights into the nature of the technological problem confronted. Moreover, it also points out that not all technological requirements lead to research needs. They may also define problems with technological information and technical assistance or problems with diffusion and adoption of technologies.

The last step in this planning process was the identification and formulation of research topics or research projects that are considered important in order to control or diminish the production problem that is faced. As pointed out earlier, this last exercise was carried out only for those technological constraints that were considered to be of high or medium priority on the basis of the previous analysis. The research projects were identified and defined by each working group using the relevant information and inputs they had at their disposal. The group discussion technique and the expert advice provided by group members were used as a means for arriving at a consensus with respect to research projects (Delphi methodology).

Table 17. Research programs formulated as part of the National Plan for Agricultural Research.

Agricultural research[a]	Animal science research
Agricultural crops	*Animal species*
Sesame	Dairy beef cattle
Cotton	Specialized dairy cattle
Rice	Beef cattle
Peas	Poultry
Oats for forage	Swine
Cocoa	Sheep
Sugar loaf (panela)	Rabbit
Barley for malt	Bees
Barley for human feed	
Coconut	*Factors of production*
Cropping systems	Physiology and reproduction
Beans	Nutrition
Fruits	Animal production
Vegetables	Pasture and forage
Peanuts	Animal health
Maize	Animal genetics
Yam	Rural socioeconomic development
African Palm	Technology economic analysis
Potatoes	Socioeconomic factors determining the adoption of technology
Plantain	Production costs and retribution factors
Sorghum	Rural employment
Soybean	Formation and functioning of capital
Tobacco	Administration
Wheat	Demand and supply studies
Cassava	Product marketing
	Input marketing
Factors of production	Land size and tenure
Entomology	Types of guild organizations
Plant physiology	
Phytopathology	Rural communication
Plant breeding	Large producers
Soils	Private technical extension workers
Water and soil resources	Institutions related to formal and nonformal education in the rural sector
Farm processes	Change agents
Farm machinery	Small farmers

[a] This does not include two major research areas (coffee and sugarcane) because in the Colombian case these areas are in the hands of the private sector.

The outcome of this process was the formulation of a set of research projects for each agricultural product, aimed at solving or controlling the principal technological constraints for that product. The different research programs thus formulated constitute the National Agricultural Research Plan, recently presented in its first version.[27]

Some Observations with Respect to the National Agricultural Research Plan

Using this methodology, a first version of the National Agricultural Research Plan has been formulated in Colombia. The plan covers four main areas: agricultural research, animal science research, research on rural socioeconomic development, and research on rural communication. The two first areas are by far the most important components.

Each area is made up of a number of research programs, each one made up of a set of research projects. Not all research programs are formulated at the level of agricultural products. Some of them refer to the technological factors that were identified in the production of crops and animals, and to the agronomical disciplines that are related to them.

A total of 63 research programs (Table 17) were formulated with the following distribution in terms of the four areas previously mentioned: Agricultural research: 33 research programs, 25 of which involve

[27] See ICA. 1981. Plan nacional de investigación agropecuaria. Five volumes.

crops and 8 involving disciplines or factors of production. It should be noted that a research program on cropping systems was included as part of the 25 programs in terms of crops. Animal science research: 14 research programs, 8 of which deal with animal species and 6 with factors of production. Research on rural socioeconomic development: formal research programs were not formulated in this area but 11 research topics were identified as being of high priority for understanding rural socioeconomic development, and supporting technological development programs. Research on rural communication: 5 areas of research were identified dealing with the principal social actors or groups that intervene in the process of rural communication. The objective is to determine the characteristics and information needs of different types of users, relative efficiency of different communication media, and role of rural communication in the process of technology transfer.

The projects that are formulated within each research program are region-specific, in terms of the geographical regions into which the country was divided. For example, the 33 research programs of the agricultural area are made up of 638 research projects. These, in turn, are distributed among the different geographical regions as follows: Andean Region, 506 projects; Inter-Andean Valleys, 414 projects; Caribbean Region, 386 projects; Orinoquia, 125 projects; Pacific Region, 25 projects. A given research project can be related to two or more regions according to the distribution and importance of a crop or technological problem in the different regions of the country.

The large number of research programs and wide distribution of topics and research areas is one of the present problems or limitations of the first draft of the National Agricultural Research Plan. This is due to the fact that the first phase of the planning methodology described earlier has not been completed. The formulation of research programs at the product level (second phase) was carried out for almost all agricultural products and not only for those that are considered to be of high priority for the country.

Thus, although research priorities have been validly assigned within products or technological factors of production (second phase), this effort is still missing at the interproduct level, on the basis of socioeconomic priorities for research purposes (first phase). The consequence of this is the large number and wide distribution of research programs that characterize the present version of the research plan.

The last step of this planning process in the Colombian case will be the completion of the first phase of the methodology, using one or both of the analytical models discussed in this paper. This will presumably narrow down both the number and wide distribution of the research programs that will finally be included in the National Agricultural Research Plan.