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ADOPTION OF HYBRID SEEDS AND FERTILIZERS AMONG COLOMBIAN CORN GROWERS

Abridged by CIMMYT

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9. ABSTRACT
Summarized in this report are the results of a study of 738 maize producers in Colombia. The study completed in 1975, is based on survey work conducted in 1973. Its purpose was to establish the extent to which various categories of farmers adopt improved technology in the form of hybrid seeds, chemical fertilizers, or both. The farms were categorized into low, intermediate, and high-altitude zones. The findings showed that services concerned with the distribution of technical assistance were provided essentially to the large growers of Zone 1 (low land), while extension services which were not necessarily connected to credit were given to small and subsistence producers. Over 32 percent of the large farmers growing maize in pure stand in Zone 1 received both credit and technical advice; another 36 percent of those farmers reported receiving only one of these services; and 32 percent used neither credit nor technical advice. The corresponding figures among the large farmers in Zones 2 and 3 were 7, 20, and 73 percent, respectively. Among all small and medium farmers growing maize in pure stand, 5 percent received technical advice and credit, 16 percent received only one or the other, and 79 percent indicated they received neither service. The data showed relatively large yield differences between farmers using the credit and technical serivces and those not using them. The main conclusion drawn from direct interviews with farmers in the three zones was that adoption levels are generally low. The level of adoption of fertilizer in Zones 1, 2 and 3 was 26, 10 and 18 percent, respectively. The level of adoption of hybrid seeds was 36, 18 and 7 percent respectively. High adoption levels occur mostly in Zone 1 among growers with favorable characteristics of size, tenure, topography, and higher levels of formal education. These are also the farmers with greater access to specialized services such as credit and professional advice. However, a relatively large proportion of adopters in the large-size group

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did not receive these services. Hybrid adoption was highly related to the use of credit. Other things equal, farmers in Zone 1 were 44 percent more likely to be using hybrids if they were also using credit. The study established that policy instruments and agroclimatic differences do affect adoption of maize technology among different farmers. However, the evidence also suggested that the policy variables, credit and technical advice, were a part of the adoption package; these services seemed to improve the opportunity for adoption, but their presence or absence may not explain adoption of hybrid maize seeds or fertilizers. There were clear differences between zones, but differences within Zone 1 were larger than those between zones. Further research is needed among producers in Zone 1 to determine the reasons for such differences and to establish the role of policy instruments. This would improve the knowledge of agricultural economics in Colombia, and provide a better base for future policy decisions.

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FOREWORD:ON LAUNCHING THE STUDIES AND MOTIVATING HYPOTHESES

Launching the Studies

The study described in the following chapters is one of a series aimed at enlarging understanding of the factors impinging on the adoption of new maize and wheat technology. Better understanding of the elements shaping the diffusion of new cereals technology can help governments and development assistance agencies to increase farmer income, hence the interest in the topic. Interest increased as controversy about effects of introducing new technologies attracted widespread attention to the theme.

CIMMYT, with its mandate defining its role in the development and diffusion of maize and wheat technology, quickly assumed a participant's role in the discussions. The concern and the interest emanating from the critical importance of the theme stimulated CIMMYT to look for a modus operandi through which patterns of adoption and the forces shaping those patterns could be identified. Better understanding of these relationships would influence CIMMYT efforts to develop new technology, the orientation of its training program, and the approach taken in counseling governments about national programs.

In order to better comprehend what influences farmer response to new technology, CIMMYT set out to facilitate the research on which this and the other studies of the series are based. We decided to examine eight cases in which maize or wheat technology had been introduced to farmers. In identifying programs for study, we limited consideration to those in which the technology had been available to farmers for no less than five years and in which no less than 100,000 hectares of land might have been affected. Eight programs were selected for study. For maize the focus was on Colombia, El Salvador, Kenya west of Rift Valley, and Mexico's Plan Puebla. For wheat, programs in India, Iran, Tunisia and Turkey were considered. CIMMYT's maize and wheat staff participated in the selection of these programs. With their knowledge of programs around the world it was possible to choose a varied set of experiences—e.g. programs with and without irrigation, with and without effective price guarantees, with massive extension effort and with virtually none.

To the extent possible, each of the adoption studies was under the supervision of an indigenous economist. In only one case was it necessary to turn to an expatriate and there we had the good fortune to collaborate with a researcher with several years experience in the area. Each of the collaborators shared CIMMYT's concern for farmer response to new technology.

Beyond sharing this concern, each collaborator had an interest in farm level research done in close cooperation with agricultural scientists. The importance of this interest emerges from our conviction that agricultural scientists who are knowledgeable about a particular maize or wheat area can contribute substantively to research on the cereals economy of that area. Their special knowledge about the interaction between plants and their environments is important in identifying agro-climatic zones, critical periods for the crop, and activities which are essential to effective cultivation. Many agricultural scientists played a prominent role in these studies; each warrants our gratitude for his contribution.

As the studies were completed it became apparent that much could be said for publishing them in a standard format. With several serving as Ph.D. dissertations and others as less formal research pieces, a common format could only be achieved through reworking the original monographs. In every case but one, then, CIMMYT's publication is an abridgement of a longer piece. The Indian study, itself a review of the findings of several other research efforts, is being published in its entirely with no effort to recast it in the form of the others.

In making the abridgement we have followed certain norms. Mathematical proofs have been eliminated, literature reviews have been included only where they relate to points which are unique to a given study, and the discussion of the hypotheses motivating the studies have been dropped. This last decision arises from recognition of the substantial commonality of these hypotheses among the studies. This suggested that, rather than presenting essentially the same discussion in the text of each abridgement, the hypotheses could be treated once in an abbreviated form for all studies. That treatment follows below.

The Hypotheses

While each of the studies examines a somewhat different set of circumstances all depart from the same general assumption about farmer behavior. The assumption is that farmers are income-seeking risk averters who are sensitive to the nuances of the environment in which they farm and that they are generally effective in their decision making. For the six studies based on original survey data and to a more limited extent for the study of Plan Puebla, this common point of departure leads to a great deal of similarity in the motivating hypotheses.

Given a farmer oriented by the assumptions described above, we might expect to see relationship between the adoption of elements of the new technolocy and: 1) characteristics of the farmer—his age, education, family size, farming experience, off-farm work, percentage of land owned; 2) characteristics of the farm—its agro-climatic region, competition of industrial crops, relative importance of cereals, nearness to markets, farm size; 3) characteristics of government programs—access to credit, access to information (through extension agent visits or visits to demonstration plots).

Some of the relationships between these variables and the adoption of elements of the new technologh are more arguable, some less. Least arguable are hypotheses relating adoption to education, farming experiences, percentage of land owned, more favored climatic regions, relative importance of cereals, nearness to markets, farm size, access to credit, and access to information. With other things equal and accepting our assumptions that farmers are income-seeking, risk-averting, sensitive, and effective maximizers, virtually no one would argue that any one of these relationships should be negative.

Somewhat more arguable is the relation of age and family size to adoption. Even here it is likely that only a few would argue that these relationships might be positive.

Most arguable are the relationships linking adoption to off-farm work and competition of industrial crops. With respect to the former, some hold that the relationship is positive as more off-farm work implies more income, therefore a greater capacity to bear risk, hence a greater willingness to adopt new technologies. Others hold the converse, arguing that more off-farm work implies less interest in the farm, hence less willingness to put in the time and energy associated with taking on new technologies. So too for industrial commodities, where those who see the relationship as positive allude to greater experience with improved inputs and larger incomes while the contrary view rests on capital restrictions and the high opportunity cost of labor.

With knowledge of the relationships among these variables, researchers and policy makers can better develop and diffuse new technologies. Some of the variables considered, e.g. age and family size, are beyond the control of these decision makers. Nonetheless, by incorporating them in the analysis the effects of variables subject to their control are more clearly discerned. Knowledge of how these variables, e.g. agro-climatic zones and extension programs, relate to adoption can be of critical importance in affecting the development and diffusion of new technology.

With this rough sketch of the general argument, readers wanting more detail about the derivation of the hypothesized relationships can turn to the relevant original piece from which this series of abridgements was drawn. In all cases the studies feature the effects of agro-climatic region and farm size on adoption of elements of new technology. This emphasis is related to the earlier controversy about the effects of new technology where these two factors played prominent roles.

Before moving into the abridgement, some attention to the phrase "elements of the new technology" is warranted. Much has been made of the concept of a package of practices in the introduction of new technology. We've chosen to look at this a bit differently, taking the view that the differences in risk, expected income, and cost of each element of the technology are large enough to outweigh the effects of the interaction among these elements. That is to say, perceptive and prudent decision makers might well choose to take up only a part of the package rather than the entire package. For the programs studies, the two dominant elements in the package are improved seed and fertilizer. These two were analyzed as dependent variables for each of the studies. Of lesser importance are such elements as seed treatment, date of planting, method of planting, use of herbicides, use of pesticides, planting density, and seed bed preparation. Nevertheless, where one of these was recommended and where data are adequate, these are also treated as dependent variables.

While CIMMYT has been associated with these studies since their inception, the opinions expressed by the authors are not necessarily endorsed by CIMMYT.

What follows:

This report summarizes the results of a study of 738 maize producers in Colombia. The study was a part of the dissertation research of Humberto Colmenares at the University of Wisconsin. Survey work was conducted in 1973, and the study was completed in 1975. This field work was supported by the Instituto Colombiano Agropecuario (ICA), and CIMMYT.

Don Winkelmann
El Batan

PREFACE

This study is the result of my dissertation research at the University of Wisconsin. I am indebted to many persons and institutions for their support during this stage of my graduate work.

I owe special gratitude to Professor Don Kanel for his guidance and friendship during my graduate school years. My appreciation is also extended to the other members of my thesis committee, Professors William Thiesenhusen, Peter Dorner, Herman Felstehausen, and Eugene Wilkening.

Don Winkelmann provided me with the opportunity to carry out this research, and Reed Hertford was always ready to help me in the initial stages of this thesis.

All persons involved in the field survey dedicated a great deal of their personal efforts and shared some difficult moments to help me gather the primary information. ICA, CIMMYT, the Ford Foundation, and the Land Tenure Center gave me their financial support to finish this research. The LTC staff helped me in different ways to achieve my goal: to all of them I am particularly grateful.

J. Humberto Colmenares
Bogota

I. MAIZE PRODUCTION AND POLICIES IN THE COLOMBIAN ECONOMY

The overall development of the Colombian economy rests heavily on the performance of the agricultural sector. The introduction and adoption of new and improved methods of production play a major role in achieving this development. The fragmented available data seem to suggest that adoption of new production methods is, in general, very limited. Thus it is important to consider those factors which may contribute to, or detract from, farmer adoption of these practices if the contribution of agriculture to development is to be enhanced. This study considers the adoption of improved maize production practices. To provide a broader understanding of the importance of this topic, we offer here some information on the role of maize in the Colombian economy.

Growth in Colombian Agriculture, 1960-1971

Agricultural production contributed approximately one-third of the Gross Domestic Product (GDP) of the country in 1960. This participation has been declining and reached 27 percent in 1971. Growth in the nonagricultural sector took place at a faster rate (i.e., 6 percent per year) than that of the agricultural sector (slightly under 3.5 percent during 1960-1971). The economy grew at 5.3 percent in the same period, as indicated by Table 1. During 1960-71, over one-half of the total value of exports (particularly coffee) and about 5 percent of the import bill came from the agricultural sector. The country's balance of trade was predominantly positive in the first half of the period under consideration. This situation reversed during 1966-1971, despite the fact that total exports increased twice as fast in this period. Import growth was related to the trade surplus of 1960-1965 and the several foreign loans received by the government during 1960-1970.[1] For the whole 1960-1971 period imports exceeded exports by Col. $1.85 billion, more than 10 percent above total export growth. Given the small participation of agricultural imports, the non-agricultural sectors are the main beneficiaries of the country's increases imports. Tha latter seems consistent with the general econimic policy of the government[2] and fullfills to some extent the role that the surplus producing sector is assumed to play in the context of most development theories. On the other hand, provided that the present economic structure does not change, the rapid increase in population will affect the capacity of the primary sector to foster economic growth.

Recent studies indicate that population growth has coincided with migration from rural areas, the appearance of shanty towns, widespread unemployment, and the impossibility of local governments to keep up with an ever-increasing demand for public services.[3] When aggregate output is compared against population, GDP per person grew at 2 percent per year and the agricultural gross product less than 1 percent.

Given the nature of Colombia's agricultural sector, output changes here occurred primarily among those few crons which constitute the core of commercial production (Table 2).

Maize Production, 1960-1970

The case of maize is especially important because of its widespread pattern of cultivation. In Colombia, maize is grown under a variety of agro-climatic conditions by both commercial and subsistence farmers, using modern and traditional methods of cultivation. Maize is one of the basic food products in the Colombia diet. Acreage devoted to maize production averaged about 20 percent of the cultivated area in major crops[4] during 1960-1972, second only to coffee. Research programs for maize go back more than 30 years. Some important achievement in this area include the establishment of one of the largest and most important collections of basic genetic material in Latin America, the production of hybrid seeds adapted to the wide variety of climatic conditions that prevail in the country, and the introduction of hybrid maize with a relatively high content of assimilatable protein. Despite the above mentioned research results and the different policy efforts to increase production, maize output did not show a clear pattern of growth during the 1960s. The same situation prevailed with regard to maize yields, as illustrated in Table 3. The latter could be related, at least on a speculative basis, to the extent to which modern inputs are used. Although the country's plant capacity for both production and treatment of improved maize seeds is well above total potential demand (in fact, the present capacity can provide enough material to seed over 100 percent of the total maize acreage), the area planted with new seeds remains less than 25 percent of the total area.[5] Fertilizer use is also low: less than 16 percent of the maize area was fertilized in any one of the years 1960-1972.[6]

Output and acreage fluctuated widely from 1960 to 1965 and decreased in 1966-1971. Yields changed with

Table 1. **GDP and population: Participation by sectors and annual rates of increase, 1960-1971.**

	Share (%) 1960	1971	Rate of Increase (%)
GDP [a]			
Total	100	100	5.3
Agriculture	33.1	27.0	3.5
Others	66.9	73.0	6.0
Exports [a]			
Total	100	100	3.2
Agriculture	55.3	54.9	3.1
Coffee	48.7	45.0	2.3
Imports [a]			
Total	100	100	8.6
Agriculture	4.5	5.1	10.7
Population			
Total	100	100	3.2
Rural	50.9	41.1	1.2
Urban	49.1	58.9	5.1

Sources: Banco de la República; National Bureau of Statistics, DANE. *a/* Deflated by the GDP Index of Implicit Prices, 1968 = 100.

production until 1965 and then rose to their initial level in the second period. Few Departamentos showed productivity gains: Valle, Córdova, Bolívar, Sucre, Cauca, and Cesar; they comprise most of the commercial farming areas. Acreage and yield reductions occurred in most areas characterized by small and subsistence agriculture.

Most of commercial farming takes place in units of relatively large size. Moreover, the distribution of maize producing farms according to sizes indicates, as in the case of the entire sector, a tendency toward bigger exploitations (Table 4).

Ten to twelve percent of the maize acreage was fertilized during 1966-1971. Nitrogen and potassium levels were relatively low compared to ICA's recommended practices. Available figures for 1972 indicate that maize growers using credit resources applied 50 percent of such recommendations. The latter is consistent with the situation encountered with regard to the entire sector.

Table 2. **Annual rates of increase and proportion of cultivated area for selected crops, 1960-1971.**

Crops	Rate of increase (%) Output	Area	Yield	Area cultivated (%) 1960	1971
All	3.2	1.6	1.3	100	100
Modern [a]	9.2	5.4	2.9	14.7	20.2
Traditional [b]	1.7	1.3	0.3	49.5	47.4
Coffee	1.7	1.9	−0.2	28.5	29.9
Wheat and barley	−3.1	−4.2	1.9	7.3	3.3

Source: Ministry of Agriculture-OPSA. *a/* Cotton, rice, sugarcane for production of sugar, sorghum, soybeans, and sesame. *b/* Maize, potatoes, plantains, cassava, beans, and sugarcane for production of *panela*.

A Description of Agricultural Regions

Geographically, Colombia could be divided into six major regions: the northern low lands, which consist of the coastal areas of the Caribbean Sea and the lower Magdalena and Cauca river flood plains; the jungles of the Pacific coast located west of the Western Mountains; the inter-Andean valleys of the Magdalena and Cauca rivers; the rugged areas and high plateaus of the three mountain ranges of the Colombian Andes; the Eastern Plains, belonging to the Orinoco basin; and the Amazon jungle south of the Eastern Plains. The *Costa* (i.e., the northern low lands) and the *interior* (i.e., both the inter-Andean valleys and the three mountain ranges of the Colombian Andes) encompass 95 percent of the total population of the country[7] and only 35 percent of the geographical area.[8] Except for both the Andean region and the Sierra Nevada in the north, the

Table 3. **Maize: Production, hybrid seed use, and fertilizer application, 1960-1971.**

Year	Output 000 mt	Area 000 ha.	Yield mt/ha	Hybrid seeds Sales mt	Area planted 000 ha.	Fertilizer N kg/ha	Fert. area 000 ha.
1960	865.7	729.6	1187	n.a.	n.a.	11.6	21.9
1961	757.5	610.8	1066	n.a.	n.a.	n.a.	n.a.
1962	753.9	696.9	1082	n.a.	n.a.	n.a.	n.a.
1963	781.6	688.8	1135	1850	108.8	15.4	27.6
1964	968.1	771.7	1254	2741	161.2	n.a.	n.a.
1965	870.8	868.9	1002	2520	148.2	n.a.	n.a.
1966	850.1	845.8	1005	2847	167.5	16.2	67.7
1967	845.0	790.0	1070	3017	177.5	15.0	94.8
1968	886.6	775.1	1144	3129	184.1	11.1	93.0
1969	790.0	681.0	1160	3239	190.5	16.5	95.3
1970	821.6	700.0	1174	2836	166.8	13.9	91.0
1971	815.7	685.9	1189	2741	161.2	12.8	102.9
1972	784.1	616.1	1272	3048	179.2	14.9	95.7

Source: Ministry of Agriculture-OPSA; and National Planning Office, unpublished data.

Table 4. **Size distribution of maize producing farms, 1959 and 1965.**

Size (ha.)	Farms (%) 1959	1965
0–4.9	26.5	18.7
5–49.9	42.3	35.8
Sub-total	68.8	54.5
50–199.9	18.0	22.8
200 and over	13.2	22.7
Sub-total	31.2	45.5

Source: Ministry of Agriculture, based on DANE, *Censo Agropecuario, 1960* (Bogotá, 1963); DANE, *Muestra Agropecuaria Nacional, 1965* (Bogotá, 1966).

territory of the country is located at altitudes ranging from sea level to 1,100 meters. Most of these areas are flat or moderately sloped. However, only about one-third of the area in the Costa and the Interior (i.e., where almost all of the cultivated land is located) is flat or relatively flat (i.e., capable of being mechanized).

Thus, the average amount of flat tillable land per farm is relatively small. A comparison of the figures of the 1960 Agricultural Census with data on the topography of the farm areas has shown that there are only 3 hectares of flat land per farm.[9] Dorner and Felstehausen report that " . . . slightly more than one half (53 percent) of Colombia's rural population is concentrated in 429 mountainous municipalities which comprise 8 percent of the national territory. In the 200 most densely populated of those municipalities there are only 1.3 hectares of land per rural inhabitant, including forest area, towns and roads, and wastelands."[10]

For purposes of this study, the country was divided into three major producing areas.[11] They are located in the Costa and Interior regions mentioned above and the Meta piedmont areas of the Eastern Plains. Within this area, zone 1 encompasses areas up to 1100 meters above sea level. The second zone includes altitudes from 1100 to 1800 meters, and zone 3 consists of areas above 1800 meters (for practical purposes, zone 3 extends to an altitude of 3400 meters above sea level).

Table 5. **Characteristics of the survey zones.**

	Zone 1	Zone 2	Zone 3
Altitude (m)	0–1100	1101–1800	Over 1800
Average farm size (ha)	24.3	16.8	2.5
Temperature range (°C)	22–32	17–24	8–20
Rainfall (mm)	1600–1800 to 2500–3000	800–1500 to 1800–2200	500–1200 to 1500–2000
Soils	Alluvial	Volcanic	Volcanic
Topography	Level	rough	rough

Source: IGAC, Atlas básico de Colombia, Bogotá, 1970, different pages, and survey data from this study.

The first zone incudes the inter-Andean valleys, the northern coastal areas (with the exception of the Guajira desert), and the Meta piedmont of the Eastern Plains, where most of the modern annual crop production takes place. Most of it is flat, with soils of relatively good characteristics. Some large areas present soils of outstanding quality, but the presence of aluminum compounds severely limits farming in the Eastern Plains. In general, crop production in that region takes place mostly in the piedmont and flood plains areas.[12] Since growing periods are shorter in the lower altitudes, farmers in Zone 1 are able to grow two crops every year. The main factor affecting the possibility of double-cropping is the pattern of rainfall, one of the main differences between the nothern coastal areas and the inter-Andean valleys. This difference could be eliminated via irrigation and/or early maturing seeds.[13] Present alternatives to maize enterprises in the modern sector include cotton, rice, suggarcane, soybeans, sesame, sorghum and beans.

Zones 2 and 3 are located entirely in the three mountain ranges of the Colombian Andes. Zone 2 is basically rough country. Coffee is by far the most important agricultural enterprise, while maize appears to be a complementary or subsistence crop. The lower areas of this zone allow double-cropping. The zone also presents two well-defined forms of agricultural exploitation: the coffee areas consisting of both relatively large farms and small diversified enterprises, and areas of *minifundio* outside the central coffee belt characterized by the cultivation of one cash crop and share-tenure arrangements. Alternatives to maize production on small farms are primarily fruit and vegetable enterprises.

Zone 3 includes some flat but mostly rough terrain. Maize enterprises are basically subsistence level since the growing season in the higher altitudes averages 10 to 11 months. Small farms are usually located in the rough parts of this zone. Commercial agriculture is devoted to dairying and production of wheat, barley, potatoes, and flowers. Vegetables are usually considered the main cash crop on small-scale farms in the highest zone. Table 5 summarizes some of the main characteristics of the survey zones.

Institutions which Determine Agricultural Policy

Productive units gain access to new forms of production within the particular institutional setting of the economy. Furthermore, institutions condition the relationships that exist in a given moment between different groups operating in the market. With regard to the agricultural sector, the institutional constraints could be defined in terms of the basic elements characterizing the country's agricultural policy: the means through which given objectives are to be achieved and the permanent evaluation of the consistency between ends and means. Policy decisions from the National Council of Economic and Social Policy are im-

Table 6. **Distribution of ICA's research facilities by zone.**

Zone	Altitude (m)	Research facilities (No.) Period when established Up to 1966	1967-1970	Total in operation	Planned
1. Low	0– 1100	4	10	14	5
2. Medium	1100–1800	3	1	4	–
3. High	2100–3200	5	1	6	–
Total		12	12	24	5

Source: Ministerio de Agricultura, *El cuatrienio de la transformacion rural:* 1966-1970, Report of the Minister of Agriculture to the Congress (Bogota, July 1970), pp. 55-60.

plemented under the direction of the Ministry of Agriculture via the allocation of resources to specialized agencies. These agencies are in turn responsible for the execution of projects designed to achieve policy goals.

Evaluation at the sectoral level takes place within the National Council of Agricultural Policy and the National Planning Office. This office, acting as the technical branch of the National Council of Economic and Social Policy, is also supposed to coordinate the public involvement in the whole economy. The organizational structure of the government within the agricultural sector is based on Decrees 2420 and 3120, both of 1968.[14] Some of the policy instruments (namely research, input production and distribution, credit, technical assistance, and extension) and the role of private groups are relevant to this study. These instruments may determine the conditions under which farmers may gain access to improved methods of production.

Organization of Agricultural Research

Research activities are basically geared to increase the productivity of land resources in order to:

> ...satisfy the demands of a rapidly growing population, supply the industrial sector with basic raw materials, and provide the country with increasing exchange earning under competitive conditions.... It is the presumption of the government that only technology, improved through research and widely spread through the agricultural sector will enable farmers to meet such a challenge.[15]

Agricultural research has been organized under the principle of unification of responsibilities and regionalization of activities. To accomplish its role, agricultural research is directed to:

a. Create technological packages for single products under the different climatic conditions prevailing in Colombia.
b. Provide basic technical support to other complementary activities such as technical assistance, extension services, quality controls for inputs, and production of specialized inputs such as seeds.
c. Improve the sanitary conditions of both plant and animal production.
d. Serve as a promoting factor in education and the advancement of technical knowledge.

ICA (Agricultural Research Institute of Colombia) is the most important public agency engaged in agricultural research. To perform its activities, ICA operates several experimental centers in the different agro-climatic zones of the country. The location of these facilities (see Table 6) gives an indication of research emphasis on medium and higher altitude crops that prevailed up until 1966. However, all but two new centers were built or are in the process of being furnished in lower areas to reflect policy decisions favoring the development of tropical agriculture.

ICA's research is focussed in terms of producing technological pakcages applicable to individual crops and according to the climatic conditions encountered throughout the different research facilities operated by the Institute.[16] Conditions are defined in relation to altitude (which in turn determines temperatures ranges) and humidity levels. The technological package refers to the specific practices that farmers are supposed to folow in order to improve their efficiency. Practices are described by the recommended levels of application of inputs, and with regard to the timing and form of utilization of either inputs or activities.

Forty-seven improved varieties developed by ICA and adapted to the farming areas of the country are currently available, 27 of them are appropriate for medium and higher altitudes (Table 7). Year-round experimental trials for different levels of fertilizer application are contrasted against the results of trials actually carried out in farmers' fields (under prevailing conditions of commercial exploitations) in order to produce a series of average recommendations for given crops. The speed with which research is developed depends partially upon the agency's ability to pay the high cost associated with the establishment of the experimental facilities. To solve this short-run bottleneck, the government has been trying to secure funds from international sources. However, given the magnitude of the problems faced within the agricultural sector, research activities have been less than adequately funded over the years. For instance, during 1960-1966 the public sector was granted loans from foreign sources for agricultural development totalling $26.7 million (Colombian pesos). This figure was substantially increased to $74.8 from 1967 until 1970. Agricultural research and related activities

Table 7. **Improved varieties available for commercial use in Colombia** [a].

Crop	Zone [b]	Approved varieties no.	Yields of best varieties (mt/ha) Experimental	Commercial [c]
Sesame	Low	1	1.2	0.9
Rice	Low	4	8.0	7.0
Oats	High	1	55.0	47.5 (Feed)
			4.8	3.8 (Grain)
Barley	High	3	3.4	2.9
Beans	Low	2	1.8	1,5
Beans	Med.	2	2.0	1.5
Beans	High	2	2.2	2.0
Maize	Low	6	8.0	6.2
Maize	Med.	4	6.5	5.6
Maize	High	6	7.5	6.4
Potatoes	Med.	1	50.0	27.5
Potatoes	High	2	38.0	27.5
Sorghum	Low	3	6.2	4.5
Soybeans	Low	4	2.7	2.4
Wheat	High	6	4.5	3.5

Source: Ministerio de Agricultura, ICA, and others, Producción y consumo de insumos agropecuarios. Mimeo. Bogotá, 1972. pp. 345-355. *a/* Includes only those varieties (and hybrids) controlled by ICA. *b/* Zones as defined earlier. *c/* Refers to trials carried out in farmers' fields.

received a negligible proportion of these resources during the first mentioned years (0.02 percent), and a little over 3 percent in 1967-1970.

Other public agencies also operate their own research facilities. This has produced duplication of activities between ICA, the Colombian Agrarian Reform Institute (INCORA) (in the case of crops), and the agricultural credit agency of the government, Caja Agraria (with regard to animal production). Some of the experimental centers are located in the same area and in some instances within walking distance of each other.[17]

Production and Distribution of Inputs

The characteristic elements of input production and distribution can be summarized in the following way. Inputs are produced by both private and public organizations. Quality standards are controlled by ICA. Use of inputs is supposed to be closely connected to the allocation of credit resources among farmers. Finally, production of certain inputs depends heavily upon external sources for basic materials. The different regulations currently being enforced with regard to external trade give the government a virtual monopoly over all imports.

Decree 140 of 1965 regulates the way in which the private sector can produce or multiply the different seeds developed through research activities carried out by ICA. It also controls the way in which basic materials can be transferred to private producers and limits the number of generations that can be obtained from the same basic materials. There are presently 29 individual producers of seeds for 10 different annual crops, with an estimated capacity of production of over 96,000 metric tons per year. As mentioned before, this plant capacity is considered satisfactory to meet the demands of the farmers.

The distribution channels are simple: it is estimated that 70 percent of the seeds certified by ICA are sold directly to farmers. Public involvement in seed production accounted for approximately one-third of total plant capacity in 1970-1972. Although use of the total plant capacity grew from 45 percent to 63 percent during the same years, actual sales remained essentially the same (a little over one-third of seed production capacity). Hence, utilization of improved seeds is relatively low in Colombia. The exception to the latter occurs in the case of a few crops within the commercial farm sub-sector.

The fertilizer industry is formed by a network of producers of basic materials, transforming or processing, and mixing plants. All potassium and approximately 70 to 80 percent of the phosphorus components are imported. Both the private and the public sectors participate in production and distribution of fertilizers. The industry could produce over one million metric tons of both urea and mixed fertilizers in 1971, up by 45 percent in relation to 1968. Utilization of the plant capacity is low, averaging about 40 percent during 1966-1971. The latter and the continuous devaluation of the Colombian currency, the dependency on the external market, and the current oil crisis may serve to explain to some extent the rapid rise in fertilizer prices with regard to the prices of the agricultural commodities.[18]

Marketing channels are relatively more complicated than in the case of improved seeds. Processing and mixing plants obtain basic components from both domestic and foreign sources. Caja Agraria is the only producer of nitrogen within the public sector with close to 20 percent of total production capacity. The rate of utilization of its plant is extremely low, averaging 20 percent during 1966-1971.[19] The mentioned agency performs all the production and marketing functions and has been able to set the pattern of distribution in the high lands. Private dealers, on the other hand, seem more important in the low and medium altitude regions. Major producer organizations play a very distinctive role at the wholesale level by providing their members with increased bargaining power.

There is an abundance of mixed fertilizers: 113 different kinds of fertilizers were sold between 1963 and 1971, 52 of them in the latter year alone. The nutrient levels of some are low: 53 percent are reported to have less than 6 percent of nitrogen content and 61 percent had less than 39 percent total nutrients.[20] Caja Agraria produces and sells fertilizer of poor relative quality, which translates into higher costs per unit of nutrient: 5-20-12 and 8-24-14, the two fertilizers most commonly used in the highlands of the central and southern plateaus are not even recommended by ICA.

Fertilizer applications increased during 1960-1971. However, available information shows that both the amount of

nutrients and the proportion of fertilized area are low or disproportionate in terms of established recommendations.[21] The average nitrogen use was 40 kilograms per hectare, or half the average amount recommended by ICA for maize.

Extension and Credit Policies

Policy decisions in the agricultural sector seek to blend together the use of modern inputs and the provision of credit resources. The extension service is then supposed to tie together these two instruments. The latter assumes a certain degree of flexibility in the input market so that farmers' demands can be efficiently met. Technical information is distributed by different agencies through extension and technical assistance services provided by both public and private organizations. As in the case of research, distribution of information is carried out for specific products on a regional basis. Technical assistance and extension are considered as separate concepts with regard to the person or agency bearing the cost of service. In the last case, the information is provided at little or no cost to the farmer. Technical assistance implies that the full cost of the service is to be paid by the person receiving the advice. Technical assistance rendered by the private sector is supposed to be tied to the provision of credit in order to promote efficiency in the use of the resources. There has been a gradual shift in the method of operation of extension through producer groups rather than through individual contacts. It is assumed that this approach will enable a wider coverage of farmers.

To carry out the responsibilities of the extension service, ICA manages a network of 64 extension agencies (up by 100 percent in relation to 1966) and 22 centers for the control of plant and animal diseases. These installations were manned by 659 technicians in 1970 (46 percent were college graduates), a four-fold increase compared with 1966.

In addition to ICA' other decentralized public agencies such as Caja Agraria, INCORA, and INDERENA run their own systems for the distribution of technical information to farmers. In certain instances the latter is the result of specific needs of investment projects financed through foreign resources, as in some of Caja Agraria's animal production projects. Both INCORA and Caja Agraria provide technical assistance or extension services as defined above. Some *Departamentos* (States) also manage local extension services. INDERENA provides information regarding conservation and management to renewable resources: these activities are restricted to fairly well-defined regions and enterprises.

This situation has produced frequent duplication among public agencies operating in the same region. Some steps are now being taken by both ICA and Caja Agraria with regard to the existence of overlapping activities within their extension services.

The allocation of credit resources to farmers is characterized by subsidized interest rates fixed by the Monetary Board at unique levels and according to specific conditions defining separate credit lines. The Central Bank (i.e., Banco de la República) gives preferential treatment via lower rediscount rates to resources being channeled to agricultural activities. Also, banks are forced to direct part of their resources to agricultural enterprises. These sources have been traditionally oriented toward short-term credit. The relative imbalance between available funds for short- and long-term ventures prompted the government to establish specific channels to favor the latter form of agricultural investment. The most recent move in this direction has been the incorporation of the resources generated through Law 26 of 1959 into the Fondo Financiero Agropecuario (the new denomination of the Fondo Financiero Agrario), referred to hereafter as FFA.

Law 26 of 1959 requires all banking institutions to set aside an amount equivalent to 15 percent of the bank's deposits. These resources were to be segregated for agricultural loans at subsidized interest rates. Since no specific enforceable controls existed with regard to the use of the mentioned resources, Law 26 became a main source of distortions within the whole credit system. FFA started operations in 1966 with the purpose of providing short-term resources to specific agricultural activities. Use of FFA's resources is supposedly controlled by means of technical assistance services fully paid by farmers. To claim access to FFA's funds farmers must grow crops covered through FFA production plans in fields of at least 10 hectares per crop, and under conditions of topography such that the operation can be mechanized. Resources for FFA are provided by participating banks (65 percent) and the Banco de la República (35 percent rediscounted credit notes). The addition of Law 26 resources meant the establishment of special conditions to accomodate FFA to long-term requirements.[22]

Thus, private banks and FFA have been designed to serve commercial agriculture. Caja Agraria, the agricultural credit agency of the government, and the Agrarian Reform Institute (INCORA) are supposed to provide credit to small and subsistence farmers.[23] From 1960 until 1965, 51 percent of all new agricultural loans were made by the two public agencies mentioned above. From 1966, when the Fondo was created, until 1971, the participation of both Caja Agraria and INCORA dropped to 38 percent. Hence, in the last half of the 1960-1971 period, the modern part of the agricultural sector received most of the additional funds (for agricultural production) generated within the institutional credit system of the country.

Farmer's access to credit resources is closely linked to the distribution of land resources. According to the 1960 Agricultural Census average farm size in Co[illegible] [illegible]er 22.6 hectares. However, the size distribution of [illegible] was highly skewed: 62.6 percent of all farms, encompassing 4.5 percent of total area in farms, corresponded to farms of less than 5 hectares in size. On the other end of the scale, 3.5 percent of all farms with 66 percent of total acreage cor-

Table 8. **Distribution of farms by size groups, 1959 and 1970.**

Size Groups (Ha.)	Farms (000) 1959	1970	Area in farms (000 ha.) 1959	1970
Less than 5	756.6	700.2	1,239	1,145
5–9.9	169.2	159.6	1,164	1,088
10–49.9	201.0	217.9	4,210	4,653
50–99.9	40.0	47.8	2,680	3,197
100 and over	42.9	51.3	18,042	20,908
Totals	1,209.7	1,176.8	27,337	30,993

Source: DANE, Boletín Mensual de Estadística, no. 274-275 (Bogotá, May-June 1974), p. 28.

respond to farms of 100 or more hectares. Preliminary figures from the 1970 Agricultural Census seem to indicate a shift in land distribution patterns toward larger farms (10 and more hectares); this change may prove a significant factor affecting agricultural growth, particularly in relation to the population increase experienced during the 1960s (Table 8).

The role of the different producer associations becomes important. These groups voice the interest of their members at the different policy-making levels and secure production outlets and specilaized services. Producers in the large farm sector are organized along the lines of specific enterprises. Their credit requests are prepared with the aid of technical advice in order to satisfy the conditions of given credit lines. For instance, farmers qualifying for FFA credit prepare production plans with the professional help procured directly or indirectly through the particular organization to which they belong.[24] That means that credit receivers from FFA (typically the largest farmers) must automatically receive technical assistance. Once FFA grants the petition, the funds are released by separate or partial installments in accordance to the mentioned plan and upon certification by the technician that specific recommendations are being followed. Credit is allocated on the basis of costs per hectare and includes all physical inputs, the value of technical assistance and interest changes accrued to the loan. Some of the major organizations such as FEDEALGODON (Federation of Cotton Growers) even provide additional credit to cover 100 percent of the production costs.

Access to services in the case of small growers follows a different approach. Farmers apply directly to any of the public lending institutions on the basis of their previous record. They are usually asked to prepare production plans which may or may not be coupled with extension visits to check its accuracy. Frequency of extension contacts is irregular and conditioned to the presence of certain plant or animal diseases.[25] Thus, for small producers, extension advice is not necessarily connected with giving of credit; furthermore, the quality of the extension personnel is usually lower (i.e., less experienced) than that of technical assistance.

Notes

1. Departamento Nacional de Planeación, "Guías para una nueva estrategia de desarrollo", in *Plan de desarrollo: objetivos y estrategias generales,* mimeo (Bogotá, 1971), Part 1; "Evaluación de la economía colombiana," in Departamento Nacional de Planeación, *Planes y programas de desarrollo.* 1969-1973. Documento DNP–417 (Bogotá, 1969). Part 2.

2. Departamento Nacional de Planeación, "Evaluación de la economía colombiana" and "Sector Agrícola", in *Planes y programas de desarrollo 1969-1973,* Parts 1 and 6.

3. Departamento Nacional de Planeación, "El empleo en Colombia: diagnóstico y recomendaciones de política," in *Revista de Planeación y Desarrollo, 2:2* (Bogotá, June 1970); W. Flinn, *The Process of Migration to a Shanty Town in Bogotá,* LTC Reprint no. 49 (University of Wisconsin-Madison, 1968); OIT, *Hacia el pleno empleo* (Bogotá: Biblioteca del Banco Popular, 1971); T.P. Schultz, *Population Growth and Internal Migration in Colombia,* Paper prepared for AID (Santa Mónica, Calif: The Rand Corporation, 1969).

4. Corn, coffee, cotton, potatoes, plantain, rice, cassava, sugarcane, sorghum, beans, wheat, soybeans, barley and sesame.

5. G. Urrego, "Semillas", in ICA, Ministerio de Agricultura, and others. Producción y consumo de insumos agropecuarios. Mimeo (Bogotá 1972), pp. 352-366.

6. G. Urrego, "Semillas," in ICA, Ministerio de Agricultura, and others. Producción y consumo de insumos agropecuarios. Mimeo (Bogotá, 1972), pp. 478-480.

7. DANE, XIV *Censo nacional de población y II de vivienda* (provisonal results) (Bogotá, October, 1974), p. 3.

8. M.R. Guerrero, *Suelos de Colombia,* IGAC, Depto. de Agrología (Bogotá, 1965), p. 196.

9. P. Ramírez, "Aptitud de explotación de suelos en Colombia," in *Agricultura Tropical,* 2:9 (Bogotá, 1965); 792-813.

10. P. Dorner and H. Felstehausen, "Agrarian Reform and Employment: The Colombian Case," in *International Labour Review,* 102:3 (September 1970): 222.

11. I am indebted to Dr. Manuel Torresgroza, senior corn researcher at ICA, who suggested the three-way classification used in the survey.

12. A. Ruiz and J.M. Spain, *The Colombian Llanos Orientales: A Preliminary Report,* mimeo (Bogotá, Rockefeller Foundation, 1968). See also C.H. Mullenax, J.S. Plaxico, and J.M. Spain, *Alternative Beef Production Systems for the Eastern Plains of Colombia,* mimeo Cali: CIAT, 1969).

13. ICA, *Evaluación programa de maíz: primer semestre de 1972.* unpublished, Mimeo (Bogotá; Grupo de Maíz y Sorgo, 1973), p. 5.

14. For a detailed discussion of the reasons behind the mentioned sectoral structure, see Ministerio de Agricultura, *Reestructuración del sector agropecuario,* OPSA, Series de Planeamiento no. 3 (Bogotá, July 1967).

15. Ministerio de Agricultura, *El cuatrienio de la Transformación rural, 1966-1970.* Report of the Minister of Agriculture to the Congress (Bogotá, July 1970), p. 19.

16. Ministerio de Agricultura, *El cuatrienio de la Transformación rural, 1966-1970,* Report of the Minister of Agriculture to the Congress (Bogotá, July 1970),p. 60.

17. There are, for instance, five research centers in the Cauca valley, three of which are less than 3 kilometers apart.

18. ICA, Ministerio de Agricultura and others, *Producción y consumo de insumos agropecuarios,* mimeo (Bogotá, 1972). pp. 168-1969.

19. ICA, Ministerio de Agricultura and others, *Producción y consumo de insumos agropecuarios,* mimeo (Bogotá, 1972), pp. 366.

20. Estimations made by the Ministry of Agriculture, based on data gathered from both producers and distributors. ICA, Ministerio de Agricultura, and others, *Producción y consumo de insumos agropecuarios,* mimeo (Bogotá, 1972), p. 217.

21. ICA, Ministerio de Agricultura, and others, *Producción y consumo de insumos agropecuarios,* mimeo (Bogotá, 1972), p. 228.

22. Law 5 of 1973.

23. Caja de Crédito Agrario Industrial y Minero, *Los problemas del crédito agropecuario y el desarrollo económico de Colombia,* paper presented to the Latin American Seminar on Rural Credit, El Salvador, October, 1968; Departamento Nacional de Planeación "Sector agrícola," in *Planes y programas de desarrollo 1969-1973,* Part 6, P. Dorner and H. Felstehausen, "Agrarian Reform and employment: The Colombian Case," in *International Labour Review* 102:3 (September, 1970): p. 232.

24. Individuals and business licensed by ICA to provide technical assistance usually work for the private producer groups, or have the endorsement of particular organizations. In either case farmers pay for their services through membership fees or direct payment, respectively.

25. INCORA's supervised credit programs in agrarian reform projects are different in the sense that services are provided with regard to individual farm plans. These projects are, however, too scattered and reach very few farmers. It has been suggested that INCORA's activities have consistently moved behind the rate of growth of subsistence farming. See O. Delgado, "La Reforma agraria: ineficaz y regresiva," in Revista Flash, 1:14 (Bogotá, September, 1970).

II. THE APPROACH OF THIS STUDY

This study is concerned with the adoption of hybrid maize seeds and fertilizers and the quantities of nitrogen used by different maize growers. For this study, a farmer who uses and hybrid seed is considered to be an adopter. The survey data show that producers plant either hybrids or local varieties and that only a negligible proportion grew both (9 out of 738).[1] Similar remarks could be made with regard to fertilizer use. The case of insecticides and herbicides is different. Small growers did not seem able to separate these two inputs. With the notable exception of DDT (extensively used in campaigns against malaria), any chemical used to kill or destroy (insects, weeds, fungus, rodents, etc.) is simply known under the general denomination of *veneno* (i.e., poison). Furthermore, the actual application is called *fumigación,* irrespective of the particular method employed to put the chemicals on plants or soil (i.e., dusting or spraying). Hence, both insecticides and herbicides were excluded from the analysis.

The independent variables define farms in terms of size, tenure, location, and topography; farmers are viewed through their attitude toward risk and the level of formal education; the delivery system is reflected by farmer's access to institutional credit and direct contacts with technical assistance and extension services.

Adoption and Farm Characteristics

Adoption of hybrid seeds and fertilizer and application of nitrogen are hypothesized to be related to farm size, tenure, and agroclimatic zone. If farms are classified according to zone, topography is also presumed to affect adoption. Several factors explain the inclusion of these variables. The size distribution of land resources is highly skewed. Big farmers have a relative advantage over those with smaller farm areas: larger farms are capable of sustaining diversified enterprises; they also may allow for the establishment of improved soil management practices, and, more important, they provide a wider economic base to attract outside resources into the farm operation.

Access to land can be gained by ownership or through contractual agreement. Agreements take two general forms: tenants (cash renters) and others (*aparceros* and *colonos*). Tenancy involves rental payment for the right to exploit a predetermined acreage. All other arrangements are different in the sense that they require rendering labor services in exchange for the use of the land. They may or may not include rental payments.[2] The relevancy of this separation refers to the limitation of the capacity to make decisions, present to a much higher degree for a farmer in the second

group. Systems of *aparcería* require farmers to work a minimum number of days in the landlord's fields. This usually coincides with peak periods of demand for labor such as planting, weeding, and harvesting. Colonos[3] are even more limited by the special characteristics of their enterprises. Restrictions as to crops that can be grown are also encountered in areas where basic foodstuffs are almost entirely supplied from local production. These limitations are not found among owners or tenants.

A relationship between agro-climatic zone and innovations is hypothesized because of differences from zone to zone in the profitability and risk associated with an innovation. Topography is closely related to zone and reflects the degree of isolation of different farms. Transportation facilities are concentrated in areas where both markets and terrain make their construction efficient and maintenance less costly. The physical characteristics of the country have led to the construction of highways and roads following the general northerly direction of the Colombian Andes and along the main river valleys and plateaus where most of commercial farming takes place.

Adoption and Farmers' Characteristics

Attitudes toward risk can be approximated in terms of evaluations of specific events whose odds are (subjectively or objectively) known. Evaluations are related to previous experiences about physical factors such as the productive capacity of the land and climatic conditions. They are also dependent upon considerations pertaining to economic constraints or ability to absorb the costs of alternative management decisions.

Attitude toward risk could be defined through farmers' evaluation of the circumstances surrounding their agricultural activities. In general, farmers characterized by a stronger dependency upon the productive results of a given agricultural season tend to be primarily concerned with risk-averting practices and decisions. Additionally, other things equal, the farm's physical endowment and the farmer's past performance will give form to specific production expectations.

Risk-averting decisions could be represented via the particular type of maize enterprise favored by the individual grower (i.e., interplanted with other crops, or cultivated in pure or single stand). It is hypothesized that the type of maize enterprise is related to both adoption and use of nitrogen. Several factors justify the choice of this variable:[4] under subsistence conditions, interplanting on the same field assures a higher level of gainful employment throughout the agricultural year; the possibility of crop failures is also diminished by this approach to product diversification; although soil depletion is increased, the additional ground cover provided through the association may reduce the need for weeding practices; competition for nutrients could also be minimized by the appropriate crop combination, fertilization, and/or decreased seeding rates. Therefore, interplanting seems a reasonable alternative to commercial farming in the presence of restricted environments curtailing the capacity of withstand risks.[5]

Production expectations are closely linked to yield variability. The assumption that farmers may be affected to a higher degree by reductions in output (i.e., total net losses are far more disruptive than relatively smaller profit margins) is introduced in order to appropriate the second element of risk evaluation. Under certain circumstances farmers are supposed capable of assessing the possibility of occurrence of particular levels of output. The questionnaire employed to collect the primary data for this research asked farmers to estimate output from their best field for both average ("normal") and less than average ("bad") agricultural years. The estimated variation gives an indication of what the farmers expect to lose as a result of adverse conditions. Implicit in the latter is the idea that productive decisions will tend to be more conservative as the mentioned gap increases. The last statement needs additional qualification in terms of the frequency with which such phenomena are thought to happen. Farmers were also asked about the number of times in a ten-year period they actually expected this difference to exist. The combination of these two dimensions made possible the creation of an "index of expectations" of yield variability. This index is hypothesized to be related to adoption and quantity of nitrogen. The direction of the mentioned relationship is both the result of the way in which the index is calculated[6] and a logical extension of the concept of rationality as previously discussed.

Adoption is also expected to be related to education. This could be explained in several ways, all of them referring to the farmers' awareness of the world. Education is really a combination of different factors such as formal training, experience as a grower, knowledge of agricultural activities, and understanding of the conditions affecting the development of the farm enterprise. The conventional definition of education (i.e., years of schooling) oversimplifies the phenomenon it intends to represent. However, it can be justified on the general grounds of its consistency with the widely accepted notion that formal education provides individuals with the capacity to use in a gainful manner opportunities offered within the institutional structure of the community.

Policy measures were approximated through access to both institutional credit and technical assistance or extension service contacts. Finally, some other variables were considered with regard to both farmer characteristics and policy instruments. However, they were found wanting in relation to their conceptualization or measurement and thus excluded from the analysis. i) Such is the case, for instance, of age, which is supposed to affect adoption in a negative way on the assumption that older farmers tend to be more conservative. However, it is possible to argue that if productive decisions and economic status are related, such an assumption does not seem appropriate: status could be gained by inheritance or personal effort over time and

neither of these situations make adoption (a productive decision) clearly dependent upon age. ii) Knowledge of crops and practices (i.e., experience) can be substituted via technical advice. iii) Off-farm work is difficult to assess for farmers with other interests which may or may not be related to maize production: large growers in the Cauca valley, or beef producers in the northern low lands, small farmers in the mining areas of Zone 3 and those associated (directly or indirectly) with coffee or tobacco in Zone 2 are examples of this situation. iv) Development literature stresses the importance of product specialization and orientation to market as indicators of degree of modernization: a general hypothesis could be established in terms of a positive dependency of adoption upon sales (either actual or usually made). Sales are the result of output, which in general varies with the use of productive methods: therefore, the mentioned hypothesis misrepresents the relationship between output, productive method, and sales. v) Very few of the farmers reporting attendance at field days or technical demonstrations could separate them from local socializing events or recall their purpose: the latter seems consistent with criticisms voiced by farmers with respect to experimental trials conducted on small farms and related to both lack of participation in the trial itself and the impossibility to learn from what the technician was actually doing. vi) Radio broadcasts are seen as entertainment rather than as a source of information about farming. vii) Membership in farmer organizations was basically directed to non-agricultural activities such as religious, sports or school groups, and Acción Comunal.

The General Adoption and Nitrogen Use Models

The general models used in connection with this thesis are summarized as follows:

Variable	*Name*	*Unit*	*Relationship*
Dependent:			
Y_1	Nitrogen	kg/ha	
Y_2	Hybrid seed	1 = use; 0 = does not use	
Y_3	Fertilizer	1 = yes; 0 = does not use	
Independent:			
X_1	Topography	1 = flat; 0 = rough	$b_1 > 0$
X_2	Tenure	1 = own-tenant 0 = other	$b_2 > 0$
X_3	Education	Years of school	$b_3 > 0$
X_4	Visits from technicians		
X_5	Yield variability (risk)	Index	$b_5 < 0$
X_6	Zone 1	1 = Zone 1; 0 = Zones 2,3	$b_6 > 0$
X_7	Zone 2	1 = Zone 2; 0 = Zones 1,3	$b_7 > 0$
X_8	Size of farm	Hectares	$b_8 > 0$
X_9	Maize enterprise	1 = pure stand; 0 = mixed	$b_9 > 0$
X_{10}	Credit use	1 = yes; 0 ; no	$b_{10} > 0$

The basic regression model employed is of the form $Y = f(X_i)$, where Y represents either fertilizer adoption, amount of fertilizer, or hybrid adoption, and X_i represents various combinations of the independent variables listed above. These regression models are estimated for the three zones separately, and for the entire sample as well

The expression $Y = f(X)$ implies that different amounts of Y will be paired to unique quantities of X. Hence, Y is assumed dependent on X and this relationship has a specific form and direction. Least square linear regression is a useful technique to analyze such relationship. However, the dependent variables Y_2 and Y_3 are expressed only as either 1 or zero. This limitation means that the distribution of the error term cannot be assumed independent of the expected estimated value of Y[7], and thus the regression coefficients (b_i values) will be unbiased and consistent but not efficient.[8] Because the error term is not normally distributed, the nominal "t" statistic cannot be used for testing hypotheses. However, we will use the t-ratio as a general indication of the significance of a coefficient, recognizing that no statistical tests of significance are possible.

The Survey Strategy[9]

Indirect or secondary sources with regard to the general situation of the country, policy aspects, and maize production were used to set the scene for this analysis (as described the first chapter). More detailed and specific information addressed to the particular objectives of the study was obtained from 738 maize growers for the 1972 agricultural year. A questionnaire containing 72 questions and describing the main relevant elements of maize production (i.e., the farm, the farmer, production methods, and measurements of policy efforts) was prepared, tested, and put into use. The final interviews were carried out from April to July 1973 by a team of 15 field workers (including the author) supported by both ICA and CIMMYT. The average length of the interviews was estimated at 45 minutes, with a maximum duration of one hour depending upon the complexity of the situation.[10]

The required number of farmers for the survey was determined using standard techniques.[11] Since farms were to be classified into two groups each for tenure, topography and size, there were a total of eight classes of farms for which adoption characteristics were to be compared. Assuming an equal number of farmers in each class, an overall adoption rate of 50 percent, a "t" of 2.0, and a significance level of 0.05, the minimum number of farms needed for each zone was 200 (25 from each of the eight classes). To provide a margin of safety, it was decided to obtain a sample of 250 farms from each zone.

The sampling technique to obtain these farmers can best

be described as two-stage sampling. The first stage was to select from each zone a sample of 150 25-hectare segments. The second stage involved the selection of 250 maize farmers from among these segments.

The sampling frame for the first stage was prepared by first compiling for each municipio in the study area the total area of the municipio and the total area in maize. (The study area included all of Colombia except Guajira, the Catatumbo region bordering Venezuela, the western coastal areas, and the areas east of the Cordillera Oriental with the exception of the Meta piedmont.) The total number of hectares of area in the municipio was then divided by 25 to determine the number of 25-hectare segments in the municipio (The segments were defined using a mapping procedure, but only for those municipios in which segments were ultimately chosen). It was assumed that the maize area of the municipio was evenly distributed among the segments, and in this manner an estimate of the area of maize in each segment was obtained. The first stage sampling frame consisted of the list of all segments in a zone. From this frame a sample of 150 segments was randomly selected with probability proportional to the area of maize in the segment. Each of the selected segments was located using the mapping procedure, and those corresponding to lakes, mountainsides, or other areas in which maize would not likely be grown, were discarded.

The second stage of the sampling procedure was to randomly choose maize producers from the farmers living in the selected segments. For each segment, all farmers cultivating some land in the segment were identified and listed. This list was randomly ordered, and the farmers were contacted in that order. Any farmer growing any maize in any of his fields (whether or not the field was located within the segment) was included in the sample of farmers surveyed. The questioning of farmers on the list for the segment was continued until three maize farmers were located, or until the list was exhausted. At this point, the procedure was repeated for the next segment in the sample from stage 1, contacting segments in the order in which they were selected in stage 1. This cycle was continued in each of the three zones until 250 farmers from each zone had been interviewed, giving a sample of 750. Of these completed interviews, 12 were later discarded because of inconsistencies or other problems discovered in the editing process.

Notes

1. This was carefully checked throughout the sample. Each farm was divided in fields in terms of specific enterprises: individual crops or crop associations were assigned a unique field number. Moreover, interviewers were instructed to consider local and hybrid varieties as separate enterprises. The farmer's answer was additionally compared with his knowledge of sources, time of acquisition, and sowing period of the seeds. These controls were also designed to avoid misclassification of those farmers replanting their own seeds.

2. This classification may only be useful within the institutional context of the Latin American rural sector, particularly regarding the socio-economic environment of the Andean countries. For a contrasting view see S. Barraclough and A. Domike, op cit.; and P. Bohanan, "Land, Tenure and Land-Tenure," in *African Agrarian Systems,* D. Biebuyck, ed. (Oxford University Press, 1963).

3. Farmers whose primary occupation is clearing up lands for further cultivation or cattle raising. Those operating on private lands are given temporary access to the cleared areas in return for their labor. Colonos in public lands seek to gain property rights through the establishment of a title claim backed by their work. The latter were not included in the sample because of their location outside the sampling area.

4. Presence of "modern" crops (see Chapter I) was initially considered in this regard. Different factors prevented its utilization as a proxy for risk evaluation: separation of sugarcane according to final use was not possible in Zones 1 and 2; coffee is grown by nearly all farmers in Zone 2, the classification of "modern" crops in Zone 3 required the introduction of additional constraints into the definition of the variable (fertilizer use, for instance, is determined to a large extent by the presence of potatoes, but this enterprise can be defined as "modern" only in association with size).

5. Use of maize enterprise does not account for the existence of adverse climatic conditions (such as partial drought) forcing farmers to grow corn in pure stands in order to assure a minimum output to satisfy consumption needs. Hence, this variable may introduce an upward bias by lumping into the same group different capacities to take risks. However, this particular weakness of the variable does not seem severe enough to alter the basic relationship between adoption and risk. In fact, farmers react to the possibility of augmented risk by scattering the actual planting of different crops over a period of time and thus avoiding the temporary competition for soil moisture.

6. The expected yield variation for the ith farmer is given by $E = [(P_n - P_b)/P_n][(10 - N)/2]$, subject to E being at least zero and no larger than 5, where P is estimated output, n and b are normal and bad years, and N is the number of normal years.

The first parenthesis in the right hand side indicates the relative decrease of production in a "bad" year. The second term estimates the number of "bad" years per decade on the assumption that "bad" and above "normal" years are equally frequent. The index (I) is then constructed multiplying E by 100/5. Therefore, farmers are assumed to be "less worried" about the possibility of wider variations in their yields as I tends toward zero.

7. See, for instance, J. Johnston, *Econometric Methods* (New York: McGraw-Hill, 1963), Chapter 7; J. Kmenta, *Elements of Econometrics* (New York: The McMillan Co., 1971), pp. 203-205, 250-254.

8. Ibid. pp. 255-256; A. Goldberger, *Econometric Theory* (New York: John Wiley and Sons, Inc., 1964), pp. 248-249.

9. The particular survey strategy followed for this thesis was suggested by Don Winkelmann of CIMMYT.

10. Particular care was exerted in the selection and training of the interviewers. The final group consisted of ten students (in the last two semesters of Agronomy at the National University), one person with ample experience in this kind of work and three recent graduates (two in Agronomy, one in Economics) at the B.S. level.

11. W.G. Cochran, *Sampling Techniques,* 2nd ed. (New York, John Wiley and Sons Inc., 1964), pp. 71-75.

III. FINDINGS FROM THE SURVEY

This chapter presents the major findings from the analysis of the survey data. It describes the characteristics of producers and maize enterprises. It also compares the adoption levels among different growers and analyzes the relationship between the use of hybrid maize seeds and fertilizers and that of quantity of nitrogen with those variables thought to affect their adoption.

Characteristics of Farmers and Farms

As mentioned before, the information refers to producers growing maize in at least one field during the 1972 agricultural year. Producer was defined in terms of the person with the responsibility of making the decisions about production. They averaged 46.5 years of age and headed households of five to six members. Only in a few cases, particularly in the mining areas of Zone 2, the producer was not the head of the household. Table 9 shows some of the differences among maize producers by zone.

Concentration in the first semester reflects the length of the growing season, the availability of water, and the relative importance of certain crops. In Zone 1, for instance, the distribution of rainfall in the Atlantic coast forces farmers to plant mostly in the second semester, while those in the inter-Andean valleys can grow in either semester; however, the largest producers in the Magdalena and Cauca valleys tend to grow more maize during the second semester and devote more effort to cotton production in the first part of the agricultural year. In the coffee producing areas of Zone 2 maize may be sown in connection to the preparation of seed beds for new coffee trees. The pattern of rainfall seems the most important factor conditioning the planting periods among farmers in Zone 3.

Figures relating to off-farm work need some qualification to account for those persons whose primary occupation is other than farming: for instance, 12 percent of those working outside their farms in Zone 1 (i.e., 9 out of 77) held steady jobs in the urban centers (i.e., physicians and lawyers). Thus, the average number of days for other farmers was actually lower (i.e., approximately 15).

Table 10 lists some factors about the efforts to provide farmers with services. As in the case of the previous table, farmers in Zone 3 show some differences when compared to those in other zones.

Of 171 farmers receiving credit, professional advice, or both, 78 percent grew maize in pure stand. Over half the pure stand maize producers receiving these services were located in Zone 1. Close to 90 percent of all the sampled farmers said they had sought information regarding means to increase production: however, 20 percent had never heard about hybrid maize and 10 percent did not know about fertilizers. Among those who knew about fertilizers, 46 percent obtained this information from neighbors or relatives, while 34 percent mentioned the same sources in the case of hybrid maize seeds, as can be determined from Table 11.

Over half of all farms were located on level terrain and 83 percent were owned or rented. The average farm size was 14.6 hectares (Table 12). Small farmers, those with 2 or less hectares, accounted for 59 percent of the interviewees, while 14 percent had 10 or more hectares of farm land. Most of those in the latter group were located in Zone 1. Farmers in Zone 2 showed the smallest proportion of land devoted to maize. The topography of the farms was also consistent with the description in Chapter I.

As mentioned before, 32 percent of all farmers grew maize mixed with other crops. This percentage was lower for Zone 1 and higher for Zone 3. Yield differences between pure and mixed stand maize were higher for farmers in Zone 1; the reported gross seed rates reflect both the type of enterprise and the availability of moisture in each of the three zones. The relatively large farm size for mixed maize in Zone 2 is partially due to the importance of coffee in such an area.

The figures in Table 13 obscure many of the differences among farmers. Such differences can be attributed to the production methods used by producers as discussed in the following sections of this chapter.

Adoption Levels for Hybrid Seeds and Fertilizers

Technological improvements have reached relatively few growers, and those using modern inputs are set apart by a series of factors related to the general (physical and institutional) environment in which they operate. Adoption levels are relatively low. Use of hybrids and fertilizers was higher among the sampled farmers of Zone 1. Adoption of hybrids was higher in Zone 2 compared to Zone 3; however, fertilizer use was higher in Zone 3 than in Zone 2. Overall adoption levels (i.e., hybrids, fertilizers, or both) among farmers in Zone 1 were twice as high as those in the other zones (Table 14). The number of producers using both

Table 9. **Characteristics of maize growers in the sample.**

	Zone 1	Zone 2	Zone 3	Total
Number of farmers	256	234	248	738
Years growing maize	17.9	17.1	24.0	19.7
Growing in first semester only (%)	21.9	46.6	96.8	54.9
Off-farm work (%)	30.1	40.6	63.3	54.9
Off-farm work (days)	37	37	52	42
Receiving income from family members not living in the household (%)	30.4	31.8	36.7	29.7

Table 10. **Policy instruments reaching farmers.**

	Farmers (%)			
	Zone 1	Zone 2	Zone 3	Total
Knowledge of agencies promoting maize	29.3	23.9	15.7	23.0
Attendance to demonstrations, field days, or experimental trials	16.0	15.8	11.3	14.3
Visits from technicians	29.3	17.9	11.6	19.8
Receiving credit	14.1	6.0	7.6	9.3

Table 11. **Sources of information about inputs:** (number of farmers).

Input	Neighbor, relative	Private or public agent	Other	Do not remember	Never heard	Total
Hybrid maize	200	374	11	6	147	738
Fertilizers	302	331	3	16	76	738

Table 12. **Farm characteristics by zones.**

	Zone 1	Zone 2	Zone 3	Total
Topography (% level or flat)	80.0	24.8	54.8	54.3
Tenure (% owners or tenants)	80.1	82.5	87.5	83.3
Farm size (ha.)	24.3	16.8	2.6	14.6
Size of maize fields (ha.)	11.7	2.5	1.4	5.3

Table 13. **Characteristics of maize enterprises by zones.**

Zone	Yield (kg/ha)	Size (ha)	Seed rate[a] (000/ha)	Farmers (No.)
Mixed maize				
1	556	8.3	14.9	68
2	567	19.4	6.6	71
3	735	2.5	6.3	98
All	633	9.2	8.9	237
Pure stand maize				
1	1180	30.1	52.4	188
2	795	15.7	42.4	163
3	913	2.7	33.9	150
All	975	17.2	43.6	501

a/ Gross seeding rates at sowing (seeds per hectare).

inputs reached more than 52 percent of the adopters in Zone 1, but less than 25 percent in Zone 2, and only 17 percent of all the adopters in Zone 3.

Adoption is low among all mixed maize growers in the three zones. Adoption levels of those in Zone 2 and 3 using a pure stand method of cultivation were also low. The only group with relatively high levels of adoption was producers growing maize in pure stand in Zone 1 (Table 15).

High adoption levels characterized only large farmers in Zone 1 who grew maize in pure stand; most of these (50 out of 56) also had flat topography and favorable tenure status. Medium levels of adoption were achieved among the remaining large and medium producers who also grew pure stand maize and had favorable tenure and topography, plus a very small group of large farmers in Zone 1 who grew maize in association with other crops. All the remaining categories (84 percent of the sampled farmers) had very low levels of adoption (Table 16).

Modern inputs are used by a small proportion of mixed stand maize growers. The decision to produce under either system of cultivation (pure or single stand) was assumed to reflect different reactions to risks as perceived by farmers. Those who favor interplanting were supposed to act as risk averters and thus be less inclined to adopt under limiting conditions. An approximation to risk perception was defined earlier as an index of yield variability (Table 17).

Among mixed stand growers, adopters of both inputs (7 out of 237 farmers) seemed to perceive a higher risk. The opposite situation prevailed among pure-stand producers. Moreover, farmers' evaluation of risks among pure-stand growers in Zone 1 is much higher for those using only one input than for full adopters. This is consistent with the earlier discussion regarding the availability of research results and professional technical advice for different farmers and systems of cultivation.

Levels of education are consistent with expectations. They show variations ranging from 2.5 to 5.8 years of formal schooling for nonadopters and adopters, respectively. School attendance among those using both inputs (i.e., full adopters) in the highest adoption group of Zone 1 averaged 8.5 years.

It can be generally assumed that adopters usually sell most of their output, while nonadopters tend to consume a relatively high proportion in the household. The reported usual sales among adopters amounted to more than 60 percent of total production. Nonadopters, on the other hand, said they generally kept about 65 percent of their output. Farmers in the high and very high adoption class (Table 16) usually sold over 90 percent. This is consistent with the earlier discussion with regard to the reasons for the selection of the different variables.

Credit and Technical Assistance, Zone 1

Proceeds from sales are needed to cover the costs of both output-increasing inputs and professional technical advice

Table 14. **Adoption levels by zones.**

Categories of adoption	Zone 1 Farmers No.	Zone 1 %	Zone 2 Farmers No.	Zone 2 %	Zone 3 Farmers No.	Zone 3 %	Total Farmers No.	Total %
Hybrid seeds	93	36.3	41	17.5	16	6.5	150	20.3
Fertilizers	67	23.2	24	10.2	45	18.2	36	18.4
Both	55	21.5	16	6.8	9	3.7	80	10.8
Hybrids, fertilizers, or both	105	41.0	49	20.9	52	21.0	206	27.9
Nonadopters	151	59.0	185	79.1	196	79.0	532	72.1
Total farmers	256		234		248		738	

to improve the efficiency of the farm enterprise. Credit and professional assistance reached a relatively small number of farmers, as indicated in Tables 10 and 18.

Concentrating the attention on pure stand growers in Zone 1, it can be readily seen from Table 19 that a very small proportion of farmers received credit only. Among small- and medium-sized producers the largest proportion obtained neither credit nor technical services, followed by the group of those receiving professional advice (and no credit).

About one-third of the large farmers used both credit and professional technical advice. The difference between large producers, on the one hand, and small- and medium-sized farmers tends to support the earlier discussion, where it was indicated that large growers obtained the combined services of credit and technical assistance, while smaller farmers usually received extension of relatively lower quality and that this service was not necessarily tied to the provision of credit.

Only two groups among medium and small producers cultivating pure stand maize are large enough for comparison: those receiving neither credit nor technical assistance and those obtaining technical assistance only. When farmers receive visits from technicians adoption levels do increase in the case of hybrid maize seeds: from 14.7 to 26.7 percent for small farmers and from 25.9 to 55.6 percent among growers cultivating medium-size farms. The adoption levels for fertilizer are much lower and do not seem consistently related to use of technical aid (Table 20).

Among large producers, however, the pattern is different. Access to technical advice alone makes almost no difference when compared to those receiving neither service: hybrid adoption levels were 84.6 and 83.3 percent and fertilizer use went from 61.6 to 55.6 percent, respectively. For those receiving credit, access to technical advice makes no difference in terms of adoption levels: all credit receivers with one exception are full adopters (i.e., both fertilizers and hybrid maize seeds).

Thus, among large farmers, adoption of hybrids is very high regardless of access to credit or technical advice; in the case of fertilizer, access to credit consistently increases its use. It is also noticeable that almost all credit receivers, regardless of size, are full adopters. However, the proportion of those receiving credit is much larger among the bigger farmers than among small and medium producers: 2.2 percent, 10.0 percent, and 44.6 percent for small, medium, and large farmers, respectively.

In summary, all large producers and all credit receivers, regardless of size, are at or near 100 percent adoption of hybrid seeds; access to credit increases the adoption levels of fertilizer among large growers; access to technical advice increases the use of hybrid maize among small- and medium-sized farmers.

When credit and technical advice are not used it is difficult to know whether there are difficulties of access to these services or if farmers are not seeking them. Therefore, it is difficult to separate whether credit and technical assistance come first and help to explain adoption (i.e., if difficulty of access to services prevents adoption by farmers who want to adopt) from the situation in which the adoption decisions comes first and these instruments are part of the adoption package (i.e., those who want to adopt ask for and obtain such services, while those who do not wish to adopt do not seek them).

The only evidence in the data for Zone 1 that may distinguish between the above possibilities relates to the comparison of the no-credit/no-visit group with the no-

Table 15. **Adoption levels by zone and maize enterprise.**

Enterprise	Zone 1	Zone 2	Zone 3	Total
Pure stand: farmers	188	163	150	501
Nonadopters (%)	51.6	74.8	77.3	66.8
Adopting fertilizers (%)	31.4	12.3	20.0	21.8
Adopting hybrid (%)	44.1	20.9	8.7	26.0
Adopting both* (%)	27.1	8.0	6.0	14.6
Mixed stand: farmers	68	71	98	237
Nonadopters (%)	79.4	88.7	81.6	83.1
Adopting fertilizers (%)	11.8	5.7	15.3	11.4
Adopting hybrid (%)	14.7	9.8	3.1	8.4
Adopting both* (%)	5.9	4.2	0.0	2.9
All: farmers	256	234	248	738
Nonadopters (%)	59.0	79.1	79.0	72.1
Adopting fertilizers (%)	26.2	10.2	18.2	18.4
Adopting hybrids (%)	36.3	17.5	6.5	20.3
Adopting both* (%)	21.5	6.8	3.7	10.8

*Full adopters.

Table 16. **Adoption of either fertilizer or hybrids by zone, topography, tenure, size, and maize enterprise.**

Adoption Levels	Categories [a]	Farmers	Nonadopters %	Adopters %
Single stand				
Very high	Zone 1; large size; flat; owners and tenants.	50	4.0	96.0
High	Zone 1; large size; other topography and tenure groups.	6	16.7	83.3
Medium	Zones 1, 2, and 3; medium size flat; owners and tenants. Zones 2 and 3; large size; flat; owners and tenants.	56	50.0	50.0
Low	All other groups	389	78.1	21.9
Mixed stand				
Medium	Zone 1; large size; all topography and tenure	8	50.0	50.0
Low	All other groups.	229	84.3	15.7

a/ Topography: flat or leveled; rough. Tenure: owners and tenants; other. Size; samll (0-2 ha); medium (2.1-9.9 ha); large (10 or more ha).

credit/visit group. The latter has many nonadopters among the small- and medium-sized farmers; this makes it more likely that extension agents contact farmers to disseminate technology rather than potential adopters contacting the agents. However, the adoption levels among the no-credit/ extension group are only slightly higher than among the no-credit/ no-extension group for small-sized farmers, suggesting that the extension effort (of the quality provided) has only little impact on adoption. On the other hand, for medium-sized producers, the adoption levels among the no-credit/visit group, 55.6 percent, are much higher than among those receiving neither service, 25.9 percent, implying that as size increases, technical advice may play a role in adoption. For the latter to hold, a similar situation should occur among the bigger farmers in Zone 1; but, as mentioned before, Table 18 indicates that technical advice may not have a significant impact on adoption. Thus, the data are not conclusive in this respect. The discussion in Chapter I, however, seems to point toward the second possible explanation in the paragraph above, particularly in relation to the results for the largest producers whose levels of adoption show very little difference among users (92.3 percent) and nonusers (88.9 percent) of credit and technical advice services.

Credit and Technical Assistance, Zones 2 and 3

As in the case of Zone 1, for Zones 2 and 3 both adoption and access to services for farmers growing maize under mixed patterns of cultivation were very low. Therefore, the discussion will center around pure stand maize growers in Zones 2 and 3.

Credit and extension or technical assistance are limited for all farmers in the medium and high altitudes (Table 21). Small- and medium-sized farmers show similar levels of access to credit and technical advice as growers in Zone 1; the biggest producers, however, receive many fewer services than their counterparts in the lower zone: 10 percent used credit and 32 percent reported receiving technical advice, against 45 and 55 percent, respectively, in Zone 1 (Table 21).

Contrary to the situation in Zone 1, large farmers do not obtain the combined services of technical assistance and credit. In fact, the differences among producers according to size are small, particularly among medium and large producers.

There are some other noticeable contrasts between Zones 2 and 3 and Zone 1. First of all, among those who reported no credit, visits from technicians increase the overall adoption levels. The change is small for producers in the small-size class (Table 22) as was the case in Zone 1.

The difference from Zone 1 for the same group (i.e., those reporting no credit) is most marked in the large-size category: although for Zone 1 adoption levels were high regardless of access to professional advice, in Zones 2 and 3 those without the latter service show relatively low adoption of hybrids and fertilizers (18.2 and 4.5 percent, respectively, against 84.6 and 61.6 percent in Zone 1), while those reporting technical help have high adoption levels.

Table 17. **Index of perceived yield variability, adoption, and maize enterprise.**

Enterprise	Nonadopters	Adopters of Fertilizer	Hybrid	Both
Mixed stand: all farmers	38.6	38.5	38.9	43.9
Single stand: all farmers	39.5	36.1	41.2	26.3
Farmers in Zone 1	40.8	45.4	44.8	22.5

Table 18. **Farmers receiving credit and professional technical advice.**

Maize Enterprise	Size [a]	% Farmers receiving: Credit, technical advice, or both (%)	None (%)	Farmers, No.
Mixed:				
Nonadopters	small	10.3	89.7	117
	larger	13.8	86.2	80
Adopters	small	36.3	63.7	22
	larger	38.9	61.1	18
Total	small	20.7	69.3	139
	larger	23.6	76.4	98
Pure stand:				
Nonadopters	small	12.0	88.0	234
	larger	11.9	88.1	101
Adopters	small	39.7	60.3	63
	larger	66.0	34.0	103
Total	small	25.1	74.9	297
	larger	60.2	49.8	204

a/ Small: 2 or less ha. Larger: over 2 ha.

Credit users (with or without extension or technical assistance) show high adoption, although the proportion of full adopters in Zone 2 and 3 is much lower than in Zone 1. Use of credit is also much lower than in the latter, the difference being largely due to the much lower use of this service among the bigger producers.

Availability of credit resources among maize producers is different between zones only in the sense that the Fondo Financiero Agropecuario—FFA does not operate in Zones 2 and 3. Thus, maize growers in the last two zones depend to a higher degree upon technical advice which could or could not be associated to the provision of credit. Although professional advice and overall adoption levels increase with farm size (comparing the no-credit/no-visit and the no-credit visit groups), the number of observations in the largest size class is too small to allow comparisons. Cross-tabulations between input and service uses yielded chi-square statistics equal to 90.4 (Zone 1) and 168.7 (Zones 2 and 3), suggesting that credit and technical advice may be more strongly related to adoption in Zones 2 and 3. The latter does not give additional information with regard to the role of services to explain adoption.

Nitrogen Application

Similar remarks can be made regarding the quantity of nitrogen and the different variables in the previous section. Therefore, it seems more appropriate to describe nitrogen application in terms of specific aspects of production and the current ICA-recommended practices.

Farm sizes are generally larger among adopters of hybrids than among nonadopters and fertilizer (but not hybrid) users (Table 23). As expected, yields increase substantially with adoption of fertilizers, hybrids, or both for those grow-

Table 19. **Farmers by size and use of services: Zone 1, pure stand growers.**

Size [a]	Farmers, no.	Farmers (%) receiving: None	Credit only	Visits only	Both
Small	92	81.5	–	16.3	2.2
Medium	40	67.5	5.0	22.5	5.0
Large	56	32.1	12.5	23.2	32.1

a/ Small: 2 or less ha. Medium: 2.1-9.9 ha. Large: 10 or more ha.

Table 20. **Adoption levels by size and use of services: Zone 1, pure stand maize.**

Size [a]	Farmers receiving	No. of Farmers	Farmers (%) adopting: None	Fertilizer	Hybrids	Both
Small	None	75	78.6	6.7	10.7	4.0
	Credit only	0				
	Visits only	15	73.3		26.7	
	Both	2			100	
Medium	None	27	74.1		22.2	3.7
	Credit only	2			100	
	Visits only	9	44.4		44.4	11.2
	Both	2			100	
Large	None	18	11.1	5.6	33.3	50.0
	Credit only	7		14.3		85.7
	Visits only	13	7.7	7.7	30.7	53.9
	Both	18				100

a/ Small: 0-2 ha; medium: 2.1-9.9 ha; large: 10 and more ha.

Table 21. **Number and percent of farmers and use of services: Zones 2 and 3, pure stand maize growers.**

Size [a]	Farmers, no.	Farmers (%) receiving: None	Credit only	Visits only	Both
Small	205	82.4	3.4	10.2	3.9
Medium	78	73.1	5.1	14.1	7.7
Large	30	73.3	3.3	16.7	6.7

a/ Small: 0-2 ha. Medium: 2.1-9.9 ha. Large: 10 and more ha.

Table 22. **Adoption levels by size and use of services: Zones 2 and 3, pure stand maize growers.**

Size [a]	Farmers Receiving	No. of Farmers	Farmers (%) adopting: None	Fertilizer	Hybrids	Both
Small	None	169	87.0	7.7	4.1	1.2
	Credit only	7		42.9		57.1
	Visits only	21	81.0		19.0	
	Both	8		50.0	12.5	37.5
Medium	None	57	87.8		8.8	3.5
	Credit only	4		75.0		25.0
	Visits only	11	54.5	27.3	18.2	
	Both	6				100
Large	None	22	77.3	4.5	18.2	
	Credit only	1				100
	Visits only	5	20.0	20.0	40.0	20.0
	Both	2				100

a/ Same as in Table 20.

Table 23. **Use of nitrogen, size of farm, and yields according to zone and categories of adoption: pure-stand maize growers.**

Category	Farmers (no.)	Nitrogen use (kg/ha)	Maize yield (kg/ha)	Farm size (ha)
		Zone 1		
Non-adopters	97	–	638	2.5
Adopters of				
fertilizer only	8	27.0	1044	7.0
hybrid only	32	–	1178	43.5
both	51	67.6	2235	78.0
		Zone 2		
Non-adopters	122	–	678	6.6
Adopters of				
fertilizer only	7	30.0	879	5.7
hybrid only	21	–	918	71.0
both	13	34.0	1646	15.7
		Zone 3		
Non-adopters	116	–	766	1.8
Adopters of				
fertilizer only	21	15.3	1171	1.9
hybrid only	4	–	1062	11.2
both	9	36.5	2139	11.7

Table 24. **Comparison of ICA recommended practices and the sample results.**

Practice	Reported by:	Zone 1	Zone 2	Zone 3
Nitrogen (kg/ha)	ICA	60-90	60-70	45-60
	Full adopters	67.6	34.0	36.5
Gross seed rates	ICA	60-66	45-50	45-50
(000 seeds/ha)	Full adopters	62.5	69.5	53.4

Table 25. **Average value of regression variables by zone.** [a]

	Zone 1	Zone 2	Zone 3	All
Topography (0 = hillside, 1 = valley)	0.81	0.23	0.55	0.64
Tenure:				
owner	0.65	0.68	0.78	0.70
renter	0.14	0.15	0.10	0.13
Other	0.20	0.17	0.13	0.17
Education (years schooling)	3.1	3.0	2.9	3.0
Visits	0.29	0.18	0.12	0.20
Yield variability	37	37	39	38
Size (ha.)	24.3	17.0	2.6	14.7
Maize enterprise	0.73	0.70	0.60	0.68
Credit	0.14	0.06	0.08	0.09
Hybrid adopters	0.36	0.17	0.06	0.20
Fertilizer adopters	0.26	0.10	0.18	0.18

a/ Averages vary slightly from those of Tables 10 and 12 because some farms were eliminated from regressions due to missing values of some variable. The numbers of farmers in the regressions were 252, 220, and 247 for the three regions, compared with 256, 234, and 248 in the sample.

ing maize in pure stand. The small number of observations in most adoption groups among those favoring mixed patterns of cultivation limits the possibility of establishing comparisons with the other producers.

Yield differences between full adopters and non-adopters are greater in Zone 1 (3.5 times) than in Zone 2 (2.4 times) and Zone 3 (2.7 times), among pure stand growers. Hybrids seem more profitable than fertilizers among producers using only one input in Zones 1 and 2, and possibly also in Zone 3, given the low cost of hybrid seed relative to that of fertilizer. Moreover, farmers in Zone 3 seem to be relatively more interested in using fertilizer than hybrids. This may reflect the greater exposure to fertilizers among producers in the higher altitudes. Potatoes, the most widely grown staple in Zone 3, are frequently interplanted with maize, and potato growers are known to be heavy users of fertilizers. However, Caja Agraria has been successful in fertilizer distribution in most areas of Zone 3. Agricultural research was until very recently primarily concerned with wheat, barley, and potatoes, all of which are cultivated in the higher altitudes only. The number of observations in each adoption class gives an indication of farmers' response to the profitability of the decision to use either input in the different zones.

Finally, full adopters growing maize in pure stand were the only group utilizing practices of cultivation within the range of ICA's recommendations (Table 24). The latter may indicate differences in the quality of the technical

Table 26. **Regression coefficients and *t* ratios for fertilizer adoption: Zone 1.**[a]

	Model 1	Model 2	Model 3	Model 4
R^2	57.7	30.6	57.7	28.2
F ratio	42.2	15.6	48.3	16.3
Constant	0.020	– 0.37	– 0.017	– 0.017
Topography				
Coefficient	0.066	0.085	0.061	0.117
t ratio	1.36	1.38	1.29	1.89
Tenure				
Coefficient	0.070	0.131	0.073	0.121
t ratio	1.46	2.15	1.52	1.95
Education				
Coefficient	0.019	0.1031	0.019	0.035
t ratio	3.42	4.42	3.39	4.98
Visits				
Coefficient	0.024	0.159		
t ratio	0.55	2.93		
Yield variability				
Coefficient	– 0.0024	– 0.0028	– 0.0023	– 0.0028
t ratio	2.88	2.54	2.87	2.59
Size				
Coefficient	0.00088	0.00081	0.00086	0.00092
t ratio	3.35	2.42	3.42	2.72
Maize enterprise				
Coefficient	0.059	0.085	0.060	0.084
t ratio	1.39	1.56	1.41	1.51
Credit				
Coefficient	0.738		0.727	
t ratio	12.60		13.16	

advice being offered to producers in the producing areas of the country.

Regression Estimates for Use of New Technology

To recapitulate, adoption of hybrids and fertilizers and quantity of nitrogen were assumed positively associated to tenure, topography, education, visits from technicians, agro-climatic zones, type of maize enterprise, size of farm, and use of credit, and negatively associated to the (estimated) index of yield variability. The definition of the variables and the reasons for their incorporation into the analysis have been previously discussed. Four models using least squares linear regression for each of the dependent variables were used with each zone separately, and for all zones pooled. Table 25 shows the average values of the variables used in these regressions.

Zone 1. Table 26 shows the regression estimates for adoption of fertilizers in Zone 1. Judging from the nominal *t*-ratios, all the variables are related to the use of fertilizer in an important way, and with the expected signs. The relationships are particularly well estimated for education, yield variability, farm size and the use of credit.

The most noticeable aspect of the models is the strong relationship between credit and visits from technicians. This can be seen in different ways: only 7 percent of those without visits and growing maize in pure stand (9 out of 129) were obtaining credit from institutional sources. On the other hand, 37 percent of the farmers receiving visits (22 out of 59) were also receiving credit. Adoption levels among those with credit were 100 percent; fertilizer use among those without credit, irrespective of visits, was low (Table 27). Thus, technical advice has no correlation to fertilizer adoption in Zone 1 when credit use is held constant. This is consistent with the discussion of the findings with respect to credit and technical assistance in Zone 1.

In model 1 visits have a negative and not significant coefficient. Reasons for this could be seen in Table 27: adoption levels among small growers receiving only visits decrease compared to those of small producers obtaining neither service, and this group represents about half of the pure stand maize producers in Zone 1. Visits from technicians become significant when related to adoption only after credit is removed (model 2); hence, visits behave as a proxy variable for credit use.

The relative importance of size is reflected by the adoption levels among those farmers not using credit: fertilizer use was higher for those in the bigger farms (58.1 percent) compared to those of medium (5.6 percent) and small (8.9 percent) size categories. The partial *r* values for size and credit ($r = 0.115$) and between size and visits ($r = 0.183$) were lower than that between credit and visits ($r = 0.382$, suggesting that size may have a net effect on adoption when credit (or visits) are held constant.

The average fertilizer adoption is 26.3 percent for farmers in Zone 1. Using the regression results (model 1), if average size of farm is doubled, the rate of adoption would increase a little over 2 percent. On the other hand, if the rate of credit use among farmers is doubled, adoption of fertilizers would increase by over 10 percent.

Education was positively and significantly related to adoption of fertilizers. Although this variable appears associated with other independent variables, it was retained in the models because of its effect on fertilizer use. Each additional year of schooling is associated with a 10 percent increase in the rate of adoption in model 2.

Thus far, the analysis has centered around models 1 and 2. Model 2 estimates the net effect of credit, visits, and education, while size seems to represent different advantages

Table 27. **Adoption levels for fertilizers among pure stand maize growers in Zone 1, according to use of credit, technical advice, or both.**

	No credit		Credit		All farmers	
Size	% Adopting	Farmers, No.	% Adopting	Farmers, No.	% Adopting	Farmers, No.
No visits						
Small	10.7	75	–	–	10.7	75
Medium	3.7	27	100	2	10.3	29
Large	55.6	18	100	7	68.0	25
Total	22.5	120	100	9	21.7	129
Visits						
Small	0	15	100	2	11.8	17
Medium	11.2	9	100	2	27.3	11
Large	61.6	13	100	18	83.9	31
Total	24.4	37	100	22	52.6	59
All farmers						
Small	8.9	90	50	2	9.8	92
Medium	5.6	36	100	4	15.0	40
Large	58.1	31	100	25	76.8	56
Total	19.4	157	96.8	31	32.2	188

Table 28. **Fertilizer adoption and maize enterprise in relation to tenure and size category: Zone 1.**

	Pure stand maize				Mixed stand maize	
	Owner-tenants		Others			
Size [a]	Non adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters
Small	45	8	23	2	34	5
Medium	22	6	6	0	20	1
Large	9	41	3	1	6	2
Chi-square	63.2		1.31		5.54	
Significance	0.001		ns.		ns.	

a/ Small: 0-2 ha; medium: 2.1-9.9 ha; large: 10 or more ha.

not included within the first three variables. However, visits from technicians are either not significant (model 1) or are only a proxy for credit (model 2), thus, they were dropped from model 3 and model 4.

Model 3 is consistent with model 1. This is simply the effect of removing visits. Comparing models 3 and 4, it can be noted that education becomes a proxy for credit. The value of the simple *r* coefficient between these two variables is 0.299; moreover, education becomes the most important variable once credit is excluded from model 4. When cross-tabulated against adoption of fertilizer, education had a chi-square of 36.5, significant at 0.001.

Finally, maize enterprise is not significant in any of the models. Cross-tabulations according to size categories between adoption and the number of farmers interplanting maize yielded a chi-square value of 5.5, which is not significant. Among those growing maize in pure stand, the introduction of tenure disadvantages reduced the value of the chi-square statistic (Table 28). This means that, as expected, size of farm is a proxy for other variables representing particular factors which may improve the opportunities for adoption of modern inputs.

The models with quantity of nitrogen as a dependent variable behaved in the same manner as those for fertilizer adoption, particularly in terms of the significance levels of the different independent variables (Table 29). The exception to this is that maize enterprise appears to be more strongly related to amount of fertilizer used than to fertilizer adoption. But this does not seem to alter the basic relationships among variables and between models. It is probably a reflection of the fact that, as in the case of adoption of fertilizers, use of this input occurs primarily among farmers with the least relative disadvantages: larger farms, flat topography, owner or tenant status, etc. As already noted, farmers who share these characteristics have in all probability a much better opportunity to ask for technical advice and credit to improve or maintain the efficiency of their farm enterprises.

Table 30 shows the regression estimates for hybrid maize adoption among farmers in Zone 1. All of the independent variables, with the exception of tenure status and index of yield variability, appear to be significantly related to hybrid adoption. The R^2 values are lower than in the case of fertilizer adoption, probably reflecting the relatively smaller effect of credit in this particular case.

The basic difference between the hybrid adoption models and those featuring fertilizer adoption is the behavior of the visits variable. Although technical advice and credit use are related, visits do seem to play an important role with regard to hybrid adoption, particularly among small- and medium-sized farmers as discussed earlier. Visits appear to be a significant independent variable related to adoption of hybrid seeds. Although its significance and its regression coefficient increase when credit is removed (model 2), visits do not act entirely as a proxy for credit as in the case of fertilizer adoption. The figures in Table 31 indicate that technical professional advice does increase adoption from 27.5 to 54.1 among those without credit and producing maize in pure stand. This was not the case for fertilizer adoption.

Although credit is still the most important variable, its effect on adoption of hybrids is smaller than in the case of fertilizers. A 10 percent increase in the number of farmers using credit would push up hybrid use by approximately 4 percent (against 7 percent with regard to fertilizer adoption). This is probably connected to the relatively low cost of hybrids. A reflection of the latter could be found by comparing hybrid adoption among large farmers in the no-credit no-visit and the credit/no-visit groups, with the corresponding adoption levels of fertilizer in the same categories; credit use does increase fertilizer adoption from 55.6 to 100 percent between the two mentioned groups (see Table 26), but it makes no difference for hybrid adoption, as indicated in Table 31.

Another important difference between the fertilizer and the hybrid models is the role of size as reflected by the similarity of the nominal *t* ratios in all four models with hybrid seed as a dependent variable. The net effect of size is still small, but not as small as in the previous case.

Education appears to lose importance compared to the fertilizer models. This may be related to the less complicated (in terms of application) nature of hybrids. The latter may also explain another difference between the two mentioned cases. The index of yield variability does not

Table 29. **Regression coefficients and *t* ratios for quantity of nitrogen in zone 1.**

	Model 1	Model 2	Model 3	Model 4
R^2	44.6	25.8	44.0	25.4
F ratio	24.9	12.3	27.8	14.1
Constant	– 0.51	– 4.12	– 1.47	– 3.51
Topography				
Coefficient	3.31	4.54	2.22	5.50
t ratio	0.80	0.94	0.54	1.17
Tenure				
Coefficient	3.81	7.66	4.46	7.32
t ratio	0.92	1.61	1.08	1.54
Education				
Coefficient	1.31	2.07	1.22	2.19
t ratio	2.73	3.77	2.54	4.06
Visits				
Coefficient	– 6.59	4.86		
t ratio	1.71	1.16		
Yield variability				
Coefficient	– 0.18	– 0.19	– 0.17	– 0.20
t ratio	2.49	2.39	2.45	2.43
Size				
Coefficient	0.09	0.08	0.08	0.09
t ratio	3.90	3.21	3.71	3.35
Maize enterprise				
Coefficient	7.72	9.33	7.86	9.30
t ratio	2.10	2.20	2.13	2.19
Credit				
Coefficient	46.15		43.35	
t ratio	9.18		9.08	

Table 30. **Regression coefficients and t ratios for hybrid adoption in Zone 1.**

	Model 1	Model 2	Model 3	Model 4
R^2	40.7	33.1	39.1	28.1
F ratio	21.2	17.6	22.8	16.2
Constant	– 0.054	– 0.087	– 0.033	– 0.56
Topography				
Coefficient	0.151	0.162	0.175	0.212
t ratio	2.4	2.45	2.81	3.15
Tenure				
Coefficient	0.033	0.68	0.018	0.051
t ratio	0.53	1.04	0.29	0.75
Education				
Coefficient	0.015	0.022	0.017	0.028
t ratio	2.11	2.94	2.41	3.69
Visits				
Coefficient	0.146	0.252		
t ratio	2.52	4.33		
Yield variability				
Coefficient	– 0.00089	– 0.0011	– 0.00094	– 0.0012
t ratio	0.84	0.94	0.88	1.05
Size				
Coefficient	0.0015	0.0014	0.0016	0.0016
t ratio	4.35	4.00	4.62	4.36
Maize enterprise				
Coefficient	0.159	0.174	0.156	0.172
t ratio	2.87	2.96	2.78	2.83
Credit				
Coefficient	0.424		0.487	
t ratio	5.59		6.71	

seem to be significantly related to hybrid adoption. Use of hybrids may involve higher risks than local varieties, particularly when rainfall patterns are not regular. However, compared to fertilizers, hybrid seeds are cheaper, easier to use, and highly divisible. Moreover, hybrids appeared more profitable than fertilizers among pure stand growers using only one of these inputs. When cross-tabulated with adoption, the index of yield variability had a chi-square value of 3.0 (compared with 13.0 for fertilizer adoption), which is not significant.

Topography is strongly related to hybrid adoption. Although flat terrain may improve the efficiency with which specific recommendations from technicians are followed (particularly with regard to seed rates and spacing of seeds), the greater importance of this variable in models 3 and 4 may be a reflection of the effect of both visits and credit.

In summary, the basic differences between the hybrid and fertilizer models seem to be that, in the case of the hybrids, visits are a significant independent variable related to adoption. Additionally, size appears a more important

Table 31. **Hybrid adoption among pure stand maize growers in Zone 1 according to use of credit, technical advice, or both.**

	No credit		Credit		Total	
Size[a]	% Adopting	Farmers, No.	% Adopting	Farmers, No.	% Adopting	Farmers, No.
No vists						
Small	14.7	75	–	–	14.7	75
Medium	25.9	27	100	2	31.0	29
Large	83.3	18	85.7	7	84.0	25
Total	27.5	120	88.9	9	31.8	129
Visits						
Small	26.7	15	100	2	35.3	17
Medium	55.6	9	100	2	63.7	11
Large	84.6	13	100	18	93.5	31
Total	54.1	37	100	22	71.2	59
Total						
Small	16.7	90	50	2	17.4	92
Medium	33.3	36	100	4	40.0	40
Large	76.4	31	96	25	85.1	56
All	32.3	157	93.5	31	42.4	188

a/ Small: 0-2 ha; medium: 2.1-9.9 ha; large: 10 or more ha.

Table 32. **Regression coefficients and *t* ratios for fertilizer adoption in Zone 2.**

	Model 1	Model 2	Model 3	Model 4
R^2	58.8	14.2	58.7	7.14
F ratio	40.1	5.3	45.8	2.9
Constant	0.018	0.031	0.022	0.070
Topography				
Coefficient	0.030	0.085	0.032	0.113
t ratio	0.93	1.85	1.01	2.38
Tenure				
Coefficient	0.048	0.027	0.050	0.041
t ratio	1.39	0.54	1.45	0.78
Education				
Coefficient	– 0.0018	0.0079	– 0.0020	0.0073
t ratio	0.45	1.36	0.51	1.21
Visits				
Coefficient	0.029	0.218		
t ratio	0.78	4.31		
Yield variability				
Coefficient	– 0.00060	– 0.0014	– 0.00068	– 0.0022
t ratio	0.93	1.55	1.06	2.31
Size				
Coefficient	0.00052	0.00035	0.00054	0.0044
t ratio	3.46	1.61	3.58	1.96
Maize enterprise				
Coefficient	– 0.0071	0.019	– 0.0057	0.034
t ratio	0.24	0.45	0.19	0.78
Credit				
Coefficient	0.936		0.951	
t ratio	15.60		16.79	

Table 33. **Regression coefficients and *t* ratios for quantity of nitrogen (kg/ha) in zone 2.**

	Model 1	Model 2	Model 3	Model 4
R^2	37.4	8.5	36.9	7.2
F ratio	16.8	3.0	18.9	2.9
Constant	– 0.09	0.37	– 0.47	1.11
Topography				
Coefficient	1.89	3,84	1.69	4.36
t ratio	1.09	1.84	0.97	2.10
Tenure				
Coefficient	2.18	1.43	2.01	1.69
t ratio	1.16	0.63	1.07	0.74
Education				
Coefficient	0.28	0.62	0.30	0.61
t ratio	1.28	2.38	1.38	2.33
Visits				
Coefficient	– 2.53	4.12		
t ratio	1.26	1.80		
Yield variability				
Coefficient	– 0.053	– 0.082	– 0.046	– 0.096
t ratio	1.50	1.95	1.32	2.32
Size				
Coefficient	0.013	0.0073	0.012	0.0090
t ratio	1.64	0.74	1.51	0.91
Maize enterprise				
Coefficient	0.53	1.45	0.41	1.74
t ratio	0.33	0.76	0.25	0.91
Credit				
Coefficient	32.90		31.64	
t ratio	10.17		10.31	

variable. Education still seems a proxy for credit in model 4, but its importance diminishes. Contrary to the situation in the case of fertilizer adoption, model 3 differs from model 1 as a result of the effect of visits and size. All R^2 values are lower in the hybrid adoption models; credit becomes less important relative to the visit and size variables, and its absence from model 2 and 4 does not reduce the coefficient of determination as much as in the case of the fertilizer adoption models. Still, the basic question as to the role of the service variables remains unanswered; this is so since adoption levels among bigger farmers (who in all probability are more likely to ask for and obtain credit and technical advice) are high, irrespective of the use of either service. Thus, the use of both credit and professional assistance is positively related to the use of modern inputs, but its presence does not explain adoption.

Zone 2. Tables 32 through 34 list the regression estimates for adoption of fertilizers, quantity of nitrogen per hectare, and adoption of hybrid seeds among maize growers in Zone 2. Credit is the most important variable related to adoption of fertilizers. The R^2 and F values are higher in those models including credit. A 10 percent increase in the use of credit (model 1) would increase the adoption level of fertilizers nearly 10 percent.

The effect of credit on fertilizer adoption may be over-

Table 34. **Regression coefficients and *t* ratios for hybrid seed adoption in Zone 2.**

	Model 1	Model 2	Model 3	Model 4
R^2	30.6	17.1	29.3	11.1
F ratio	12.4	6.7	13.4	4.7
Constant	- 0.17	0.0078	0.0015	0.036
Topography				
Coefficient	0.031	0.069	0.041	0.101
t ratio	0.50	1.22	0.78	1.74
Tenure				
Coefficient	– 0.018	– 0.032	– 0.010	– 0.017
t ratio	0.32	0.53	0.17	0.27
Education				
Coefficient	0.0084	0.015	0.0075	0.014
t ratio	1.29	2.12	1.13	1.97
Visits				
Coefficient	0.121	0.252		
t ratio	2.01	4.04		
Yield variability				
Coefficient	0.0014	0.00084	0.0011	– 0.000036
t ratio	1.34	0.73	1.04	0.03
Size				
Coefficient	0.00104	0.00092	0.0011	0.00103
t ratio	4.24	3.45	4.47	3.74
Maize enterprise				
Coefficient	0.063	0.081	0.069	0.098
t ratio	1.31	1.55	1.42	1.83
Credit				
Coefficient	0.645		0.709	
t ratio	6.62		7.64	

stated. It is possible that credit use is summing up the effects of other unmeasured variables associated to specific characteristics of Zone 2. This zone includes the central coffee belt where maize production is generally a minor enterprise. The coffee sector has been traditionally able to secure a relatively large share of both credit and specialized services, and small coffee producers have access to such resources. Thus, it is likely that fertilizers are used in maize fields in connection with the production of coffee (particularly at the early stages of growth of the coffee trees, or in association with the preparation of seedbeds among small growers).

The four models featuring kilograms of nitrogen per hectare as a dependent variable behave in the same way as the fertilizer adoption models. Credit is the only significant variable, but when it is omitted, education, yield variability and visits become more important.

Both visits and size of farm were positively and apparently significantly related to adoption of hybrids. Model 2 suggests that visits (despite their association with credit) are a significant independent variable. Their effects should be larger in terms of the adoption of hybrid seeds alone rather than in relation to the adoption of both hybrids and fertilizers.

The negative association between credit and size and the strong positive relationship of credit and visits suggest that the effect of size on adoption of hybrid seeds should be larger among those receiving credit compared to producers without credit. Model 2 indicates that after credit has been removed visits become the most important variable, while the importance of size is reduced. As in Zone 1, the relationship between size and adoption is apparently statistically significant but marginal in size. A 10 percent increase in average farm size in Zone 2 would increase the adoption levels of hybrid maize seeds less than 2 percent.

Zone 3. The regression estimates for Zone 3 are included in Tables 35 through 37. Credit is the only significant variable in the fertilizer adoption models. Models 1 and 3 are essentially the same; hence, visits are in all probability a proxy for credit.

The models featuring amount of nitrogen per hectare behave much in the same manner as for fertilizer adoption. The only difference appears with respect to topography and size. However, the net effects of these variables (as indicated by the corresponding regression coefficients) is very small. The negative sign of the coefficient of topography indicates that adoption tends to be higher among farmers located in rough terrain: the sample shows that fertilizer adoption reached 21 percent among those in rough

Table 35. **Regression coefficients and *t* ratios for adoption of fertilizer in Zone 3.**

	Model 1	Model 2	Model 3	Model 4
R^2	29.1	4.0	29.0	2.7
F ratio	12.2	1.4	14.0	1.1
Constant	0.110	0.078	0.108	0.093
Topography				
Coefficient	– 0.043	– 0.068	– 0.044	– 0.63
t ratio	1.02	1.39	1.05	1.27
Tenure				
Coefficient	0.050	0.072	0.052	0.064
t ratio	0.78	0.96	0.81	0.85
Education				
Coefficient	– 0.0041	0.0014	– 0.0044	0.0036
t ratio	0.43	0.13	0.46	0.32
Visits				
Coefficient	– 0.022	0.139		
t ratio	0.32	1.80		
Yield variability				
Coefficient	– 0.000043	0.0030	– 0.000025	0.00020
t ratio	0.05	0.30	0.03	0.34
Size				
Coefficient	0.0015	0.0059	0.0014	0.0068
t ratio	0.45	1.54	0.43	1.76
Maize enterprise				
Coefficient	0.0059	0.050	0.0062	0.050
t ratio	0.13	0.99	0.14	0.99
Credit				
Coefficient	0.771		0.764	
t ratio	9.18		9.43	

Table 36. **Regression coefficients and *t* ratios for quantity of nitrogen (kgs/ha) in zone 3.**

	Model 1	Model 2	Model 3	Model 4
R^2	23.4	6.7	22.7	3.0
F ratio	9.1	2.5	10.1	1.3
Constant	0.57	– 0.14	0.88	0.54
Topography				
Coefficient	0.0028	– 0.55	0.13	– 0.29
t ratio	0.002	0.42	0.11	0.22
Tenure				
Coefficient	1.47	1.94	1.31	1.60
t ratio	0.82	0.98	0.73	0.79
Education				
Coefficient	0.26	0.38	0.29	0.47
t ratio	0.95	1.28	1.08	1.59
Visits				
Coefficient	2.73	6.26		
t ratio	1.42	3.07		
Yield variability				
Coefficient	– 0.029	– 0.024	– 0.024	– 0.024
t ratio	1.13	0.74	1.23	0.90
Size				
Coefficient	– 0.015	– 0.05	– 0.13	– 0.012
t ratio	1.56	0.49	1.46	0.12
Maize enterprise				
Coefficient	1.56	2.52	1.52	2.55
t ratio	1.28	1.89	1.52	1.88
Credit				
Coefficient	16.58		17.69	
t ratio	7.22		7.82	

areas and 15 percent for producers with farms on level ground. However, farmers in the latter group applied 21 kg/ha of nitrogen, while those in rough topography used only 15 kg/ha. Hence, the negative sign of topography in models 2 and 4 results in all probability from the exclusion of credit, which is negatively associated with topography (r = 0.043). Similar remarks could be made regarding the coefficient of size. These results are consistent with the particular characteristics of Zone 3 as described in Chapter I.

Finally, the models including hybrid adoption as a dependent variable show that credit, visits, and size are important independent variables positively associated to adoption of hybrids. Although credit is the most important variable, the net effect of visits could be important: in model 1, for instance, a 10 percent increase in the number of farms visited would increase adoption of hybrids by a little over 1 percent. The sample data shown in Table 38 suggest that visits may be more important in fertilizer adoption than is indicated by the regression results, particularly among the medium and large farms of zone 2 and 3.

Summary of Regression Results. Regression models for fertilizer adoption, level of fertilizer, and hybrid adoption were estimated for all zones pooled. The results are report-

Table 37. **Regression coefficients and *t* ratios for hybrid adoption in Zone 3.**

	Model 1	Model 2	Model 3	Model 4
R^2	22.2	16.1	20.0	11.5
F ratio	8.5	6.6	8.7	5.3
Constant	0.078	0.088	0.064	0.070
Topography				
Coefficient	0.39	0.031	0.044	0.037
t ratio	1.36	1.04	1.54	1.25
Tenure				
Coefficient	0.037	0.044	0.030	0.035
t ratio	0.86	0.98	0.70	0.77
Education				
Coefficient	0.0072	0.0089	0.0085	0.011
t ratio	1.11	1.33	1.31	1.68
Visits				
Coefficient	0.114	0.165		
t ratio	2.49	3.59		
Yield variability				
Coefficient	– 0.00029	– 0.00018	– 0.00038	– 0.00030
t ratio	0.51	0.31	0.67	0.50
Size				
Coefficient	0.0079	0.0093	0.0084	0.010
t ratio	3.55	4.07	3.71	4.42
Maize enterprise				
Coefficient	0.044	0.057	0.042	0.058
t ratio	1.49	1.91	1.42	1.88
Credit				
Coefficient	0.243		0.279	
t ratio	4.34		5.09	

ed in Tables 39, 40 and 41, along with the coefficients from the full models in each of the zones for reference. The regression models for adoption differ from those previously estimated in that tenure has been broken down into two dummy variables for owners and renters as opposed to all others (share croppers, colonists and communal tenure). The effect of this change on the estimated coefficients of the other variables was negligible. The sizes of the coefficients obtained from the pooled models are consistent with those from the individual zone models, as are the *t*-ratios and nominal *t*-ratios. Additional models were estimated for the pooled data, eliminating credit and extension visits, but since the results were essentially the same as those obtained for individual zones, the results are not reported here.

We can summarize the results of these various regression models by considering the significance of those factors related to policy (extension visits and credit), versus those related to farm and farmer characteristics (tenure, education, perceived yield variability, farm size, maize enterprise, and topography).

The effects of extension visits and credit use on fertilizer adoption are highly interrelated, especially in zones 1 and 2. The regressions indicated that extension visits had little or no effect on adoption, except when they occurred in

Table 38. **Adoption of fertilizers and hybrids among nonreceivers of credit.**

	Zone 1			Zones 2 and 3		
	% Adopting		Farmers,	% Adopting		Farmers,
Size	Fertilizer	Hybrids	No.	Fertilizer	Hybrids	No.
Small						
No visits	10.7	14.7	75	8.9	5.3	169
Visits	0	26.7	15	0	19.0	21
All	8.9	16.7	90	7.9	6.8	190
Medium						
No visits	3.7	25.9	27	3.5	12.3	57
Visits	11.2	55.6	9	27.3	18.2	68
All	5.6	33.3	36	7.3	13.2	68
Large						
No visits	55.6	83.3	18	4.5	18.2	22
Visits	61.6	84.6	13	40.0	60.0	5
All	58.1	76.4	31	11.1	25.9	27

conjunction with credit use. In Zone 3, however, farms which had received extension visits were about 3 percent more likely to use fertilizer, over and above the effect of extension visits which occurred as a part of credit use. Farms using credit were from 74 percent (Zone 1) to 94 percent (Zone 2) more likely to be using fertilizer. However, since the decision to use fertilizer and the decision to use credit are interdependent, it is not possible to determine the effect of the credit programs themselves.

Due to the low incidence of either credit (9 percent of all farms) or extension visits (20 percent of all farms), the estimated total impact of these policy instruments on fertilizer adoption has been small. For example, the regression coefficients imply that the lower rates of credit use and extension visits in Zones 2 and 3 account for only 5 to 7 percent lower rates of fertilizer adoption in those areas, compared to Zone 1. On the other hand, an increase of 10 percent in the number of farmers receiving credit would appear to increase fertilizer adoption on the order of 7 to 10 percent and fertilizer rates on the order of 2 to 4 kg/ha. However, this study has not explored the factors affecting farmer use of credit.

The effect of extension visits on *hybrid* adoption is more pronounced, however. Quite apart from the effects of credit use, farms which had received extension visits were from 12 to 15 percent more likely to use hybrids than farms without visits. As was the case for fertilizer adoption, credit users were much more likely (25 to 65 percent more likely) to be using hybrids, but again it is impossible to determine from these results the effects of the credit program alone. As noted above, the level of extension visits and credit use is low and because of this they have had little total effect on hybrid use. The lower rates of credit use and extension visits in Zone 2 and 3 account for only 3 to 5 percent less hybrid adoption in those areas than in Zone 1. The regression results imply that an increase of 10 percent in farmers receiving credit would increase hybrid use by 2 to 6 percent, and an increase of 10 percent in farmers receiving extension visits would increase hybrid use by about 1 percent.

The effects of farm and farmer characteristics on adoption of fertilizer and hybrids were of the expected signs, but in general each one alone explains very little of the variability in adoption levels among farms or among zones. Exceptions to this are topography and type of maize enterprise in Zone 1. In this zone, about 15 percent more of the

Table 39. **Regression estimates for fertilizer adoption in all zones.**

	Zone 1	Zone 2	Zone 3	All
R^2	0.58	0.63	0.29	0.48
F ratio	37.1	40.5	10.8	59.4
Constant	0.017	0.013	0.110	0.051
Topography				
Coefficient	0.065	– 0.007	– 0.045	0.012
t ratio	1.3	0.2	1.0	0.5
Tenure				
owner				
Coefficient	0.088	0.036	0.049	0.067
t ratio	1.8	1.0	0.7	2.3
renter				
Coefficient	0.009	0.028	0.074	0.039
t ratio	0.1	0.6	0.8	1.0
Education				
Coefficient	0.018	0.0004	– 0.004	0.010
t ratio	3.2	0.1	0.4	2.7
Visits				
Coefficient	– 0.030	0.020	– 0.021	– 0.003
t ratio	0.6	0.5	0.3	0.1
Yield variability				
Coefficient	– 0.002	– 0.0002	– 0.000	– 0.001
t ratio	2.7	0.3	0.0	2.3
Size				
Coefficient	0.0008	0.0004	0.0016	0.0007
t ratio	3.2	3.1	0.5	4.1
Maize enterprise				
Coefficient	0.064	– 0.009	0.007	0.030
t ratio	1.5	0.3	0.2	1.3
Credit				
Coefficient	0.74	0.96	0.77	0.81
t ratio	12.5	17.0	9.1	20.6
Zone 1				
Coefficient				0.011
t ratio				0.4
Zone 2				
Coefficient				– 0.078
t ratio				2.8

Table 40. **Regression estimates for quantity of nitrogen in all zones.**

	Zone 1	Zone 2	Zone 3	All
R^2	0.45	0.37	0.23	0.39
F ratio	24.9	16.8	9.1	51.2
Constant	– 0.51	– 0.09	0.57	– 3.15
Topography				
Coefficient	3.31	1.89	0.0028	
t-ratio	0.80	1.09	0.002	
Tenure				
Coefficient	3.81	2.18	1.47	3.59
t ratio	0.92	1.16	0.82	2.02
Education				
Coefficient	1.31	0.28	0.26	0.99
t ratio	2.73	1.28	0.95	4.58
Visits				
Coefficient	– 6.59	– 2.53	2.73	– 2.09
t ratio	1.71	1.26	1.42	1.17
Yield variability				
Coefficient	– 0.18	– 0.053	– 0.029	– 0.10
t ratio	2.49	1.50	1.13	3.64
Size				
Coefficient	0.09	0.013	– 0.015	0.448
t ratio	3.90	1.64	1.56	4.73
Maize enterprise				
Coefficient	7.72	0.53	1.56	3.80
t ratio	2.10	0.33	1.28	2.72
Credit				
Coefficient	46.15	32.90	16.58	35.80
t ratio	9.18	10.17	7.22	14.99
Zone 1				
Coefficient				7.78
t ratio				4.80
Zone 2				
Coefficient				– 0.96
t ratio				0.59

farmers on flat land were using hybrids, and about 15 percent more of those farms with pure stands of maize were using hybrids. This could be an indication that communication and information is much better among these more commercialized farmers, or it could indicate that hybrids have a greater economic advantage under these circumstances as compared to farms on rough terrain and farms which grow maize intermixed with other crops.

Roughly speaking, extreme differences among farmers in the level of these characteristics (2 standard deviations) would have at most the following impacts on the probability of a farmer adopting either fertilizer or hybrids: tenure, 8 percent; education, 10 percent; risk perception, 10 percent, farm size, 20 percent. What these numbers suggest is that there is no single dominating farm characteristic which tends to determine whether or not a farmer will adopt fertilizer or hybrids. A farmer well above average in all characteristics would be 50 percent more likely to adopt than would the average farmer. But judging from the coefficients of multiple correlation of the regression equations, farm and farmer characteristics do not explain a large part of the variability in adoption patterns among farms. The same is true for variability in adoption among zones. These factors taken together account for a reduction of 2 to 3 percent in fertilizer adoption rates in Zones 2 and 3 compared to Zone 1, and a reduction of 3 to 5 percent in hybrid adoption rates.

The coefficients of the dummy variables for Zones 1 and 2 in the pooled regression equations allow an estimate of the differences in adoption levels between zones which are not attributable to the other variables in the equations. Consider, for example, fertilizer adoption, which was 26, 10 and 18 percent in the three zones, respectively. Nearly all the difference between Zones 1 and 3 is accounted for by the difference in policy variables and farm characteristics variables. Fertilizer adoption in Zone 2, however, is about 8 percent lower than the other two regions, apart from the effects of the variables just mentioned. These regression models do not allow us to determine the causes of this difference. Hybrid adoption was 36, 18 and 7 percent in the three zones, respectively. Comparing Zones 2 and 3 with Zone 1, only about half the reduction in adoption in Zone 2 is attributable to the variables in the regression models, and only about a third of the reduction in Zone 3 is due to these variables. The remaining unexplained difference could be due to differences in the relative economic advantage of hybrids in the three areas, it could be due to differences in the availability of seeds in the three areas, or to differences in the general level of knowledge about hybrids in the three areas. However, the relatively small impact of extension visits in Zones 2 and 3 suggest that knowledge is not the explanation. It was not possible within the scope of this study to determine whether or not differences in relative yield advantage or seed availability were significant enough to explain the remaining differences in hybrid adoption among the three zones.

Table 41. **Regression estimates for hybrid seed adoption in all zones.**

	Zone 1	Zone 2	Zone 3	All
R^2	0.42	0.32	0.23	0.40
F ratio	19.5	12.3	7.9	42.5
Constant	– 0.03	– 0.02	– 0.08	– 0.13
Topography				
Coefficient	0.142	0.019	0.033	0.083
: ratio	2.3	0.3	1.1	3.1
Tenure				
owner				
Coeffeicient	0.026	– 0.058	0.30	0.009
t ratio	0.04	1.0	0.7	0.3
renter				
Coefficient	0.006	0.008	0.113	0.042
t ratio	0.1	0.1	1.8	1.0
Education				
Coefficient	0.017	0.011	0.008	0.017
t ratio	2.3	1.8	1.2	4.3
Visits				
Coefficient	0.121	0.124	0.120	0.131
t ratio	2.1	2.1	2.6	4.0
Yield variability				
Coefficient	– 0.0013	0.002	– 0.0004	– 0.0003
t ratio	1.2	1.8	0.7	0.7
Size				
Coefficient	0.0014	0.0010	0.008	0.0013
t ratio	4.3	4.2	3.6	7.0
Maize enterprise				
Coefficient	0.166	0.044	0.046	0.080
t ratio	3.0	0.9	1.6	3.1
Credit				
Coefficient	0.441	0.66	0.24	0.438
t ratio	5.9	7.0	4.3	10.1
Zone 1				
Coefficient				0.177
t ratio				6.0
Zone 2				
Coefficient				0.100
				3.2

IV. SUMMARY

This study dealt with adoption of improved technology among maize growers located in different producing areas of Colombia. Improved technology was defined in terms of the use of hybrid seeds, chemical fertilizers, or both.

The first part of the study was devoted to examining the conditions under which farmers operate. Attention was given to policy measures concerning the provision of credit and technical advice to the agricultural sector. These measures were mostly associated with short-term objectives seeking to increase production and foreign exchange earnings. Services concerned with the distribution of technical assistance were provided essentially to the large growers of Zone 1, while extension services which were not necessarily connected to credit were given to small and subsistence producers. Over 32 percent of the large farmers growing maize in pure stand and located in Zone 1 received both credit and technical advice; 36 percent of those in the same group reported only one of these services; while 32 percent used neither credit nor technical advice. The corresponding figures among the large farmers in Zones 2 and 3 were 7, 20, and 73 percent, respectively. Among all small and medium farmers growing maize in pure stand, 5 percent received technical advice and credit, 16 percent reported obtaining only one or the other, and 79 percent indicated neither service.

The available information shows relatively large yield differences between farmers using the mentioned services and employing modern inputs and those using no such services or inputs. These differences appeared more marked among producers located in the lower areas (Zone 1) served by the Fondo Financiero Agrario.

The main conclusions drawn from the analysis of the information gathered via direct interviews with 738 farmers located in three agro-climatic zones were the following. Adoption levels are generally low. The level of adoption of fertilizer on maize among the low (Zone 1), medium (Zone 2) and high (Zone 3) altitude areas was 26 percent, 10 percent and 18 percent, respectively. The level of adoption of hybrids was 36 percent, 18 percent and 7 percent in the three zones. High adoption levels occur mostly in Zone 1 among growers with favorable characteristics of size, tenure, topography, and higher levels of formal education. These are also the farmers with greater access to specialized services such as credit and professional advice. However, a relatively large proportion of adopters in the large-size group did not receive these services.

Hybrid adoption rates differed considerably among the low, intermediate and high altitude zones (36 percent, 18 percent and 6 percent, respectively, of farmers used hybrid maize). Least-squares regressions explained 42 percent, 34 percent and 23 percent of the variability in hybrid adoption behavior among farmers within the three zones, and 40 percent of the variability in behavior among farmers in the entire sample. The regression coefficients suggested that farmers who had received extension visits were about 12 percent more likely to be using hybrids than those who had not, other things equal. In other words, about 12 percent farmers visited could be expected to adopt hybrids as a result of the visit. Hybrid adoption was also highly related to the use of credit, the other policy variable considered in the analysis. Other things equal, farmers in Zone 1 were 44 percent more likely to be using hybrids if they were also using credit. The corresponding figures for Zones 2 and 3 were 66 percent and 24 percent. This suggests that scarcity of investment funds may be a more important factor inhibiting hybrid use in Zone 2 than in the other two zones. It was beyond the scope of this study to determine what factors affected farmers' decisions with respect to credit use, and to what extent that decision was related to the decisions to use fertilizer and hybrids.

Several of the farm and farmer characteristics were related to hybrid use with the expected sign. Education increased the probability that a farmer would be using hybrids, but each year of education increased that probability by only about 1 percent. Farm size was also significantly related to the probability of adoption, but again, a 10-hectare increase in farm size was related to an increase of only 1 to 2 percent in the probability that a farmer would adopt. Thus the evidence of important economies of scale in hybrid use is slight once other factors are considered. There was some evidence that the hybrids are more suited to pure maize stands than to maize which is intercropped. Farmers with pure stands were 17 percent more likely to adopt hybrids in Zone 3, but only about 5 percent more likely to adopt in the other two zones.

Topography was important in hybrid adoption. In Zone 1, valley farmers were 14 percent more likely to adopt than were hillside farmers. The corresponding figure of the other two zones was only 2 to 3 percent. Further evidence of the agro-climatic adaptability of the hybrids was the fact that apart from the effect of other variables considered, hybrid adoption was 18 percent higher in Zone 1 than in Zone 3, and 5 percent higher in Zone 2 than in Zone 3.

Fertilizer adoption varied less from zone to zone than

did hybrid adoption. The proportion of farmers using fertilizer on maize in the three zones was 26 percent, 10 percent and 18 percent, respectively. There is no clear explanation for the fact that in Zones 1 and 2 only about two thirds as many farmers use fertilizer as use hybrids, while in Zone 3, three times as many farmers use fertilizer as use hybrids. Furthermore, after correcting for the effects of other variables, farmers in Zone 3 could be expected, from the regression estimates, to use fertilizer to the same extent as farmers in Zone 1, though only one sixth as many in Zone 3 used hybrids. The most plausible explanation for these differences is that hybrids and the hybrid distribution system are more highly developed in Zone 1 than in Zone 3, while the fertilizer distribution system and fertilizer responses are more nearly similar in the two areas.

Of the two policy variables hypothesized to affect fertilizer use, visits by technicians seemed to have no affect on fertilizer use, while the use of credit was associated with an 80 percent greater probability that a farmer would be using fertilizer, and with an additional 35 kg/ha of nitrogen. The impact of credit was greater in Zone 2 than in the other zones, again suggesting that scarcity of funds is a greater impediment to adoption there.

Of the farm and farmer characteristics hypothesized to affect fertilizer use, several were significantly related with the hypothesized signs. The most important of these was farm size, for which each 10-hectare increase in size was associated with a 1 percent increase in the probability of fertilizer use, and an additional 5 kg/ha of nitrogen. Since average farm size differed by more than 20 hectares across zones, this relationship explains significant differences in fertilizer use. While fertilizer is a divisible input and as such does not involve economies of scale, this relationship probably reflects better information, greater availability of investment funds, and a greater ability to absorb risks on the part of the larger farmers.

Land owners were 6 percent more likely to use fertilizer than other tenure categories, and used on the average about 4 kg/ha more nitrogen. Education also affected fertilizer use, with an extra year of education increasing the probability of fertilizer use by about 1 percent, and average level of nitrogen use by about 1 kg/ha. Yield variability (perceived risk) was slightly negatively associated with fertilizer use, as hypothesized, and farmers growing maize in pure stands were both more likely to be using fertilizer and used more fertilizer on the average, as was hypothesized.

The distribution of extension visits and credit among farm sizes, was found to be quite uniform in Zone 2 and 3, but was found to highly favor the larger farmers in Zone 1. Since the adoption behavior of larger farmers in Zone 1 seemed to be little affected by these services, the implication of this finding is that such services should be redistributed toward the smaller farmers in that zone.

Finally, this study was able to establish that policy instruments and agro-climatic differences do affect adoption of maize technology among different farmers. However, the evidence also suggested that the policy variables, credit and technical advice, were a part of the adoption package; thus, these services seemed to improve the opportunity for adoption, but their presence or absence may not explain adoption of hybrid maize seeds or fertilizers. The maize producing areas of Zone 1 encompass more of the advantageous characteristics for the use of modern technology than the other two zones; however, differences within Zone 1 were larger than between zones. Therefore, further research will be needed among producers in Zone 1 in order to accomplish two complementary goals: to determine the reasons for the existence of such differences and to establish the role of policy instruments regarding the introduction of modern methods of production. Research projects of this sort would improve the knowledge of the economics of the agricultural sector of Colombia and would provide a more appropriate framework on which to base policy decisions seeking to improve the growth of the economy.