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AN ECONOMIC ANALYSIS OF FERTILIZER UTILIZATION IN BRAZIL

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

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* * * * * *

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CHAPTER I

INTRODUCTION

Traditional agriculture largely depends upon land and labor for its output while the transition to a modern agriculture is marked by the use of a number of new inputs, technological change, and improvement in the quality of traditional inputs. One of the most prominent features of this transition is the rapid increase in use of chemical fertilizers. Over the 1966/67 to 1968/69 period worldwide fertilizer use increased at an average annual rate of 8 percent. Usage of chemical fertilizer in South America increased more rapidly, averaging 25 percent in the same period.[1] In some cases fertilizer use has been stimulated by dramatic changes in technologies, e.g. new seed varieties which are highly responsive to plant nutrients, irrigation, or mechanization. In other cases fertilizer use has been spurred by concessional prices, credit incentives, or educational programs. By almost any measure, chemical fertilizer has become and will likely continue to be a key factor in accelerating agricultural development.

In the process of capital formation, fertilizer plays an important role in increasing gross and net revenue, thus increasing the

capacity for investment. The existence of marketing and transportation facilities for fertilizer use indirectly makes these facilities available for other inputs and products in the rural sector. The use of fertilizer may also change the structure of the capital assets of a farm firm; a larger portion of capital must be in liquid assets to be used for operating expenses. This normally will cause an increase in the percentage of product which is marketed thereby transforming the farm from a traditional type of agriculture to a market oriented unit.

This study will focus on recent changes in fertilizer utilization in Brazil. Not only has Brazil sharply increased its fertilizer use recently, but it also has been very active in adjusting policies which affected the profitability of fertilizer application. The objectives of this study are: 1) to estimate the value of the marginal product of fertilizer application on several crops in one region of Brazil; 2) review Brazil's fertilizer policy; and 3) suggest policy changes and research priorities based on the findings in 1) and 2)

Justification

The agricultural sector has five major functions to perform in the process of economic transformation.[2] It must: (1) increase domestic food supplies, (2) increase agricultural exports to obtain foreign exchange, (3) transfer labor to the industrial sector, (4) contribute to capital formation through lower prices for agricultural products and taxes, and (5) provide a market for industrial products.

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[2] B. F. Johnston and J. W. Mellor, "The Role of Agriculture in Economic Development," American economic Review, 41 (September, 1961), pp. 566-93.

An increase in agricultural production is a precondition to the fulfillment of any of these functions, and fertilizer is usually a key factor in stepping up production.

In many respects Brazil is an excellent case to study with regard to the economics of fertilizer application. It has experienced rapid changes in fertilizer usage in the past 20 years and has also employed a variety of policy instruments to encourage these changes. On the output side, for example, minimum support prices were established for most of the food crops. At various times, fertilizer received consessional import exchange rates and special subsidized credit. The Agency for International Development (AID) supported these efforts with loans and loan quarantees for new production facilities and programs designed to stimulate utilization totaling $67.9 million.[3] Mainly as a result of these programs, fertilizer consumption in Brazil has increased threefold from 250,000 tons (metric) in 1961 to 820,000 tons in 1970 and the private marketing sector has expanded accordingly.

Although fertilization rates have increased rapidly, there is almost a complete lack of information available with regard to the crop response to fertilizer at the farm level. It is not known if present application levels have reached or surpassed optimum levels

Methodology

The government price and credit subsidies for fertilizer are based on the assumption of positive net returns to fertilizer use,

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[3]Agency for International Development (AID), "Brazil Program Analysis", unpublished manuscript, (on file AID Washington D.C. 1970, Annex H), pp. 28-38.

however, this assumption has not been sufficiently tested as to its validity at the farm level in Brazil. The major objective of this dissertation is to test this assumption by estimating the parameters of production functions for four crops in one region of Southern Brazil. This analysis ignores the non-crop portion of the farm operation, thereby assuming the opportunity cost of capital to be zero. The employment of specific crop production functions, however, is necessary to derive accurate estimates of the marginal product of fertilizer components (N, P_2O_5, K_2O) and other complementary inputs such as seed, insecticides, etc. The remainder of this chapter outlines the order and manner in which the objectives of this dissertation are analyzed.

The Brazilian fertilizer situation and policy is reviewed in the second chapter. The discussion is divided into those factors affecting supply (production, imports, marketing and price policy) and the factors influencing demand (productivity, management, information services and credit policy). The major focus of this chapter, however, is on the economics of fertilizer use on the farm level and all topics are discussed with respect to their effect on the farm operation.

The area and sample is described in Chapter III. Management levels, Credit and fertilizer use, tenure, and enterprises are the major topics covered in this description. The conceptual model used in the productivity analysis is explained in Chapter III. A description of the sample farms and the characteristics of specific variables entering the productivity analysis are also presented in this chapter.

The analysis of crop yields with respect to fertilizer and other inputs is presented in Chapter V.

The specific aspects of the previous descriptive and quantative analysis which have major implications for Brazilian fertilizer policy are outlined in Chapter VI. Major emphasis is placed upon exploring the technical implications of the productivity analysis.

The conclusions and recommendations for further research are made in Chapter VII.

CHAPTER II

ECONOMIC ISSUES RELATED TO FERTILIZER USE IN BRAZIL

This chapter reviews important economic issues related to fertilizer use. It includes a survey of relevant literature and an overview of fertilizer use and policy in Brazil. The major objective is to provide perspective for the farm-level productivity analysis presented later in the study. For presentation purposes the issues are organized under the headings of supply and demand. Because of the focus of this study, particular emphasis is placed on the latter. The discussion begins with a conceptual outline of these issues. A brief review of fertilizer use and policy in Brazil follows to set the stage for the supply and demand discussions in the latter part of the chapter. A brief summary of the major points made is given in conclusions.

Conceptual Outline

A comprehensive fertilizer study would include an analysis of factors affecting supply and demand. It will be argued later that in Brazil, problems on the demand side appear to be most critical. Nevertheless, a conceptual outline of the supply side, some

information on local fertilizer marketing conditions, and descriptive material on past supply conditions should be helpful in understanding the farm-level productivity analysis.

Supply

As will be shown later, fertilizer imports have been an important part of Brazil's overall supply. An analysis of imports as well as domestic production would, therefore, make up an important part of a supply analysis. Imports, on the one hand, are primarily a function of the level of domestic production, world prices, effective domestic demand, and government foreign exchange policy. Domestic production, in turn, is primarily dependent on the costs of labor, raw materials and capital, plus world prices and technical transformation coefficients. Current governmental policy includes protection of domestic industry, while at the same time not allowing a large difference between domestic and world prices of fertilizers. Brazil's fertilizer purchases in the world market are of a magnitude which does not effect world price.

The production and importation of fertilizer is only part of the supply picture. The workings of the internal marketing system provides transportation, storage, soil analysis, credit, fertilizer application recommendations, and other information. All of these functions, along with the competition factor, affect the price at which fertilizer can be delivered to the farmer. These market services, aside from the price effect, may also have an influence on the demand for

fertilizer by increasing the knowledge of the farm manager

Demand

The demand for fertilizer is a derived demand based on the value of the marginal product from fertilizer in agricultural production. In this study the factors analyzed are placed in production function form:

$$Y = f(F, I, L, M)$$

Where Y = quantity of output

F = quantity of fertilizer

I = quantity of other variable inputs

L = land

M = management

Economic theory suggests that a firm seeking to maximize profits under conditions where opportunity costs $\leq$ value of the marginal product, or no budget constraints, each factor will be used to the level where the ratio of its value-of-the-marginal-product-to-its-price equals one. Thus, the demand for fertilizer depends upon the marginal products of all inputs, the product prices, other input prices and fertilizer prices. Management, while not a direct input into the production process, can affect the returns to inputs through proper timing of application, planting depth, etc. Unfortunately these are not influences which can be easily measured.

In most cases the assumption of an unlimited budget is unrealistic. It is for this reason that the volume of credit available is included in the following discussion. Credit does not enter the production process directly, but may be a constraint on the use of inputs, especially fertilizer, and thereby influence the marginal productivity and demand for an input.

Brazilian Fertilizer Usage, 1950 to 1970

Agricultural production in Brazil has more than doubled since 1950, and the amount of cultivated area has also increased from less than 20 million hectares in 1950 to approximately 35 million in 1970.[1] The agricultural sector has undergone many rapid and complex changes during the last twenty years. A number of detailed analyses of the Brazilian agricultural sector are available.[2]

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[1] John Shotwell, "FY 1970 Agricultural Sector Analysis-Brazil" (unpublished paper in USAID/Brazil files, Rio de Janeiro, July, 1969), p. 24.

[2] G. E. Schuh and E. R. Alvis, The Agricultural Development of Brazil (New York: Praeger Publishers, 1970), p. 456; Peter T. Knight, Brazilian Agricultural Technology and Trade, (New York: Praeger Publishers, 1971), p. 223; W. H. Nicholls and R. M. Paiva, Ninety-Nine Fazendas: The Structure and Productivity of Brazilian Agriculture (Nashville: Vanderbilt University, 1966); C. Prado et. al., A Agricultural Subdesenvolrida (Petropolis: Editora Vozes Limitada, 1969), p. 275; and G. W. Smith, "Brazilian Agricultural Policy, 1950-1967," The Economy of Brazil, H. W. Ellis, ed. (Berkeley: University of California Press, 1969), pp. 213-65.

During these 20 years of agricultural growth the utilization of fertilizer in Brazil has gone through three distinct stages. From 1950 to 1960, consumption grew at an annual rate of approximately 15 percent per year and fertilizer use per cultivated hectare doubled.[1] The national political situation changed dramatically during the period 1961 to 1966 however, and the consumption of fertilizer was affected adversely. Consumption dropped to 80 percent of its 1960 level by 1962, and in 1966 was still below its 1960 level. Due also to a steady increase in cultivated area, consumption per hectare was at only 75 percent of its 1960 level in 1966. According to a 1964 study, only 5 percent of the Brazilian farmers used fertilizer.[2]

A rapid increase in the use of fertilizer began in 1967. Consumption of fertilizers increased by more than 100 percent from 1966 to 1968 and reached 820,000 metric tons by 1970, triple the 1966 level. This approximates an annual rate of increase of 35 percent during the four year period. In terms of bulk weight, the imports via the port of Santos, the main import point, increased from

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[1]Statistics of fertilizer consumption are given in Appendix E.

[2]Agri-Research, Estudo Tecnico-Economico Sobre A Exequibilidade de Aumento Na Fabricacao e Uso de Fertilizantes, Calcario e Sais Minerais No Brasil (Rio de Janeiro: AID, 1964), pp. 65-185.

1.0 million tons in 1969 to 1.5 million tons in 1970.

Fertilizer utilization per cultivated hectare reached 18 kilograms in 1968 for Brazil. In Sao Paulo, average use rose above 50 kilograms of plant nutrients per cultivated hectare in 1970, an average which is greater than the average application rate in the United States in 1960.[1] The usage of lime to correct soil acidity also more than doubled from 340,000 tons in 1966 to 748,000 tons in 1970 in the state of Sao Paulo.

A major part of the chemical fertilizer use in Brazil is concentrated in the central and southern regions. The central region including Sao Paulo, used 68 percent of the total in 1968, while the South used 24 percent. The North used only 8 percent mostly for sugar cane. The South has been increasing its usage of fertilizer however at a higher rate than other regions largely due to increased plantings of wheat and soybeans.[2]

As can be seen in Table 1, a significant proportion of the area in several different crops in the Center and South received fertilizer.

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[1] E. Malavolta, "Tendencia na Adubacao," Jour nal do Estado de Sao Paulo, (February 21. 1971).

[2] Studies of the national fertilizer situation in Brazil have been made by: Agri-Research, Inc., op. cit., p. 303; Banco Nacional Do Desenvolvimento Economico, Mercado Brasileiro De Fertilizantes 1950-1970 (Rio de Janeiro, 1965), p. 56; Joao Braga Costa, "Agricultural Inputs: Fertilizers," (unpublished paper in USAID/Rio files, Rio de Janeiro, 1969), p. 34; Associacao Nacional Para Difusao De Adubos, (numberous published papers, Sao Paulo, 1968-1970).

TABLE 1.--Percentage of area fertilized by crop and region, Brazil, 1968.

Crops	North	Center	South
Coffee	. . . %	50.0%	. . . %
Corn	0.0	50.0	29.9
Sugar Cane	40.0	39.7	0.0
Wheat and Soybeans	. . .	42.9	57.6
Rice	0.0	24.8	49.8
Cotton	0.0	52.5	. . .
Potatoes	. . .	100.0	0.0
Edible Beans	0.0	9.8	9.8
TOTAL	8.9	45.6	39.3

Source: P. V. Belotti, "Perspectivas da Industria de Fertilizantis no Brasil," (Paper given at the UNIDO meeting on the Development of Fertilizers and Pesticides Industries in Latin America, Rio de Janeiro, November 16-20, 1970).

Supply of Fertilizer

Production

The majority of the fertilizer used in Brazil has been imported. Domestic production has varied from a high of 42 percent in 1964 to a low of 20 percent of domestic use in 1970. Domestic production has increased although not rapidly during the last decade. In 1963 large increases in domestic production were projected. Three companies which produced 13,022 tons of nitrogen in 1963 planned on having an output of 93,000 tons in 1969.[1] Partly because of the sharp drop in world prices for nitrogen during the late 1960's, this

goal was not reached. Domestic production of nitrogen actually dropped to 6,460 tons in 1969.

Imports of fertilizer generally have not been restricted in Brazil by quota systems. Exchange rate manipulation has been used however to alter the real import price of fertilizer. On occasion Brazil's fertilizer producer's have received direct subsidies to prevent any losses due to lower priced imports.

Nitrate deposits are lacking in Brazil, therefore all nitrogen must be artificially produced or imported. From 1947 to 1957, the only domestic production of nitrogen was a by-product, ammonium sulfate, from the steel industry in Volta Redonda, Minas Gerais. Two other plants based on petroleum by-products began production in 1958 and 1963, respectively. Ultrafertil began building a plant near Santos, Sao Paulo, in 1967. It was to begin production in 1969 and reach an output of 123,000 tons by 1973. This plant, partially financed by a $15 million AID loan and further AID backed loan guarantees of $18 million, has experienced delays in construction and more importantly, it is expected to have difficulty in matching the prices of imported fertilizer. This is primarily due to large and unforeseen decreases in the world price of nitrogen fertilizers after the planning process for the plant was completed. In 1965-66, the world price of ammonium sulfate was US$ 45-50/ton and by 1969 had

fallen to US$ 21/ton

The production of phosphate fertilizers in recent years has progressed at a fast pace, although it has not kept up with consumption. Brazil does have phosphate resources of a magnitude that it can be self-sufficient. The problem is one of exploration, production, and transportation at competitive prices. Deposits are located in Sao Paulo, Minas Gerais, Pernambuco and Maranhao. Estimates made in 1964 predicted a domestic production of 192,000 tons by 1970.[1] Actual production in 1969 was 128,000 tons, 69 percent of the projected production. Future plans project large increases in domestic production, particularly in the state of Minas Gerais which is near the major consumption areas.

Potassium fertilizers are totally imported as no commercially profitable deposits are known in Brazil. The National Company of Potassium Fertilizers planned to develop potassium sulfate deposits in the Northeast, but no production has occurred. Table 2 presents the future production facilities which are in progress. These projects only include nitrogen fertilizers except for the guano exploration project.[2]

[1] Agri-Research, Inc., op. cit., p. 104.

[2] Guano is an island bird which produces a nitrogen-rich manure.

TABLE 2. -- Future Brazilian production facilities

Producer	Location	Tentative Production Date	Products	Capacity (tons/yr.)
Petrobeas	Bahia	1970	Ammonia	48,500
Ultrafertil	Sao Paulo	1970	Ammonia	148,500
			Ammonium Nitrate	434,000
			Ammonium Phosphate	158,400
Tibeas-Titanio do Brasil	Bahia	1970	Sulphuric Acid	110,000
Government Project	Ilha Dasratas	. . .	Guano Exploration	. . . .

Source: Food and Agriculture Organization of the United Nations, Fertilizers: An Annual Review (Rome: 1970), p. 46.

Marketing

The marketing structure for fertilizer in Brazil is almost entirely handled by the private sector and is quite complex. At one extreme, some companies have modern production and/or mixing facilities, and a system of service centers which provide credit, soil analysis and application facilities. At other extreme, a few farmers arrange for fertilizer importation, transportation and application without intermediaries.

In Sao Paulo, for example, the center of the fertilizer industry,

39 mixing companies operated 183 warehouses, employed 175 inspectors, 2,000 salesmen, and 72 agronomists in 1966.[1] Only a few of these had capital investment larger than US$ 1.5 to $2.0 million. The six largest companies market 30,000 to 60,000 tons of fertilizer per year, equal to US$ 3 to US$ 10 million.[2]

There are two viewpoints with respect to marketing systems in developing countries. The first is that the marketing system is relatively efficient and any excess profit is eliminated through competition from new firms entering the market.[3] The second view holds that the present marketing system is inefficient and government

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[1]Agency for International Development, "Proposal and Recommendations for the Review of Development Loan Committee: Brazil Fertilizer Imports," (unpublished paper Washington, D. C., 1964).

[2]Agency for International Development, "Capital Assistance Paper: Brazil-Ultrafertil, S. A.," (unpublished paper Washington, D. C., August, 1966), p. 14.

[3]G. W. Smith, op. cit., pp. 221-22; G. L. Johnson "Factor Markets and Economic Development," Economic Development of Tropical Agriculture, ed. W. W. McPherson, (Gainesville: University of Florida Press, 1968), pp. 93-111.

programs are necessary to improve its efficiency.[1]

Adequate documentation supporting either view with respect to fertilizer is not available. The aspect mentioned frequently to justify public marketing organization is summarized in the following statement:[2]

> The lack of organized markets insures that a long chain of intermediaries in the marketing channels exploits both producers and consumers.

The high costs of entering the rural market and the small initial size of market are frequently mentioned as causes of imperfect agricultural marketing systems.[3] A study of the input marketing system

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[1]Charles Slater et. al., Marketing Processes in the Recife Area of Northeast Brazil, Research Report No. 2, (East Lansing: Latin American Studies Center, Michigan State University, 1969), pp. 12-7-12-11; A. T. Mosher, Promoting Agricultural Growth: A Framework for Organization Planning (New York: Frederick A. Praeger, 1966), p. 172; K. L. Bachman and R. P. Christensen, "The Economics of Farm Size," Agricultural Development and Economic Growth, ed. H. M. Southworth and B. F. Johnston (Ithaca: Cornell University Press, 1967), pp. 252-54.

[2]Clyde Mitchell and Jacob Schatan, "The Outlook for Agricultural Development in Latin America," Agricultural Development in Latin America: The Next Decade, (Report of a Round Table, Inter-American Development Bank, Washington, D. C., 1967), p. 54.

[3]T. W. Schultz, Transforming Traditional Agriculture (New Haven: Yale University Press, 1964); Vernon Rutian, "Southeast Asian Agricultural Markets," Agricultural Cooperatives and Markets in Developing Countries, ed. R. K. Anshel (New York: Frederick A. Praeger, Inc., 1969), pp. 153-56.

in Northeastern Brazil supported this view and concluded that government programs of research on fertilizer response, promotion activities, subsidies to private marketing firms to extend their facilities, and direct distribution through government organizations were necessary.[1] No evidence was presented however, with respect to excessive profit margins and discrimination in the present system or thata public system would be more efficient. A more recent study in Northeast stated that retail fertilizer margins are not unreasonable or considerably higher than in other regions of Brazil.[2] Results from studies of the Thailand fertilizer marketing system found little evidence of exploitation, but found considerable market entry and exit, and price competition.[3] The high rate of failure of marketing cooperatives in Thailand also supports the view of a relatively efficient marketing system.

[1]Charles Slater et. al., op. cit., pp. 10-14.

[2]Raymond White, "The Fertilizer Industry in Northeast Brazil" (unpublished paper in USAID/Recife files, Recife, 1969), p. 41.

[3]B. J. Bond, T. M. Kelso, and R. O. Woodward, "A Report on the Thailand Fertilizer Situation and Potential"(paper prepared for AID, Washington, D. C., 1966), p. 61; E. D. Smith and J. E. Berry, "A Study of Retail Fertilizer Markets in Northeastern Thailand Some Preliminary Findings" (unpublished paper delivered at the Annual Masetert University Agricultural Conference, February, 1971), p. 19.

The retail fertilizer marketing system in the sample region of Ribeirao Preto was composed of thirty-five dealers.[1] There appears to have been a rapid growth in the fertilizer marketing infrastructure in this region. In the sample group, seven of the sixteen interviewed dealers began on or after January 1, 1966 and only six were selling fertilizer prior to 1960. The lack of capital requirements such as storage, transportation and application facilities made entry to the fertilizer market very easy, but transferred these requirements to the farmer. There are two different types of dealers in the region: a few company dealerships and a large number of independent agents. The company dealership usually operated from one of the major cities of the area, had one or more professionally trained agricultural specialists, a number of salesmen, storage facilities, credit service, andsold fertilizer and agricultural chemicals in several municipios. The independent agent was either a company intermediary or an independent dealer who bought fertilizer in large quantities and resold it or a mixture of these two types. He normally sold a wide variety or other agricultural inputs and also bought agricultural

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[1] The following discussion is based on information gathered in 62 interviews with extension agents, bankers, statistical officiers and fertilizer dealers in the region of Ribeirao Preto, Sao Paulo. Sixteen of the 35 fertilizer dealers in the region were interviewed.

products, therefore receiving less than half of his income from fertilizer sales. He usually operated in one to two municipios, sold one to three fertilizer brands, and would furnish credit to his clients.

The variation in fertilizer prices in the region was rather high (Table 3).

TABLE 3.--Dealer list prices of selected fertilizers per ton in 1969/70, Ribeirao Preto Region[a]

Types[b]	Range of Prices[c] Low	High
3-15-15	Cr$ 278	Cr$ 350
4-14-8	270	325
NH_4SO_4(21%N)	210	255
KCl (60%K_2))	260	363
Super Phosphate (20% P_2O_5)	210	255

[a]These are the average-on-farm-prices as given by the dealers for the agricultural year 1969/70 including transportation cost of Cr$20-30/ton from Sao Paulo to the farm.

[b]Sold by four or more dealers.

[c]One U. S. dollar equals approximately 4.25 cruzeiros.

Source: Interviews with 16 fertilizer dealers, Ribeirao Preto Region, December, 1970.

Factors which may explain the differences in on-farm-price are: (1) price information is not generally known by farmers; (2) certain dealers may have a monpolistic selling position; (3) some dealers allow a one-two month payment period without charging interest, but may include this service in the fertilizer price; (4) independent dealers are not tied to the companies' list price and may be able to increase fertilizer prices during periods of highest demand; and (5) dealers with storage facilities in the area may charge indirectly for the service. Interest charged on loans granted by dealers also exhibited large differences ranging from 12 to 36 percent per year. If these differences actually reflect variations in services provided by dealers, the effect on the economics of fertilizer use would be nil. Analysis of these hypotheses is not within the scope of this study or possible with the available data.

Storage, application equipment, and soil analysis were provided by only a few dealers. Credit services of the dealers and their companies appeared to be good except in terms of cost when compared to FUNDAG. Many dealers were also performing a valuable extension service by aiding farmers to get bank credit and in soil analysis.[1]

[1]A more detailed description of the local marketing system is presented in William C. Nelson, Fertilizer Marketing-Brazil, Research Note No. 3, (Columbus: Department of Agricultural Economics, Ohio State University, 1971), p. 10.

Price Policy

With the exception of governmental intervention in coffee prices, there was no government price policy in Brazil until 1945. At that time, an emergency plan established minimum prices for most of the major food crops. The system was made permanent in 1951 and the coverage extended to more products.

Fertilizer prices in Brazil are primarily a function of transportation costs, world fertilizer prices and the government controlled import exchange rates.[1] A multiple-exchange rate was established prior to 1950 to tax certain exports and selectively subsidize or tax certain imports. In 1969, the multiple-exchange rate was dropped and replaced with selective export taxes (called exchange retentions) which perform the same function. The relative price of fertilizer was lowered during the gradual expansion of fertilizer consumption from 1950 to 1960.[2] A ratio, based on the fertilizer price index to a product price index (1948 to 1952 period equals 1.00) decreased from 1.01 in 1950 to 0.52 in 1959 and then rose to 1.23 by 1965. After the 1961-66 period of stagnation in fertilizer consumption, the price ratio dropped to approximately 0.76 in 1967 and has averaged 0.77 during the last four years when consumption has increased very rapidly.

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[1] Raymond White, op. cit., pp. 3-7.

[2] See Appendix E for the indices.

The assumption that farmers in developing countries do not respond to price changes has been seriously challenged during the past ten years. Assumptions associated with this point of view are summarized by Schultz.[1] His main thesis is that traditional agriculture"...is at an economic equilibrium under the present technological and economic situation and that changes in the environment faced by farmers are necessary to stimulate agricultural growth." Later studies have verified that farmers in developing countries do respond to economic incentives.[2]

In Sao Paulo, the supply elasticities with respect to product prices for cotton, rice, corn and soybeans were found to be positive

[1]T. W. Schultz. op. cit., pp. 7-15.

[2]W. P. Falcon and C. H. Gotsch, "Relative Price Response, Economic Efficiency and Technological Change: A Study of Punjab Agriculture," Report No. 11, Development Advisory Service, (Cambridge: Harvard University, February, 1967); C. K. Eicher, "The Dynamics of Longterm Agricultural Development in Nigeria," Journal of Farm Economics, Vol. 49, No. 5, (December, 1967), pp. 1158-70; and D. E. Welsch, "Response to Economic Incentives by Abakaliki Rice Farmers in Eastern Nigeria," Journal of Farm Economics, Vol. 47, No. 4, (November, 1965), pp. 900-14.

and high.[1] These supply elasticities indicate that Sao Paulo farmers are very responsive to economic incentives on the output side (Table 4). Substitution of one crop for another, as estimated by the

TABLE 4.--Supply and cross elasticities of selected agricultural products, Sao Paulo, Brazil

Crops	Supply Elasticity Short Run	Supply Elasticity Long Run	Cross Elasticity
Corn	0.83	3.32	-0.14
Cotton	0.37	a	a
Rice	0.42	0.69	-0.32
Soybeans	1.21	a	-0.76

[a]Not Available

Source: N. K. and R. M. C. Pescarin, "Projecoes Da Oferta Agricola Do Estado De Sao Paulo," Agricultura em Sao Paulo, Ano XVII, No. 9/10, (September, 1970), p. 57.

cross elasticity, was also significant for corn with respect to the price of rice, rice with respect to corn price, and soybeans with respect to corn price. The response of total agricultural production to price changes was not estimated in this study, however the supply

[1]N. K. Toyama and R. M. C. Pescarin, "Projecoes Da Oferta Agricola Do Estado De Sao Paulo," Agricultura em Sao Paulo, Ano XVII, No. 9/10, (September, 1970), p. 57.

elasticities are greater in absolute value than the cross elasticities implying a postive aggregate supply elasticity.

The demand for fertilizer, as previously stated, is derived from the demand for the final product. Economic theory states that the major factors determining the usage of variable input such as fertilizer are the value of its marginal product and its price, however little success has been obtained in estimating demand functions for fertilizer based on price relationships. Three early studies in the United States found no relationship between fertilizer price and consumption.[1] A strong relationship was found between fertilizer consumption and the farm size and income variables in two of the studies. A more recent study found short-run demand elasticity to be -.5 and a long-run elasticity to be -2.0.[2] The functional

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[1]E. E. Vail, "Prices of Fertilizer Materials and Factors Affecting the Fertilizer Tonnage" (unpublished Ph. D. dissertation, Cornell University, 1927); A. L. Mehring and B. T. Shaw, Relationships Between Farm Income and Farmer's Expenditures for Fertilizer and a Forecast of the Commercial Demand for Fertilizer in 1944 and 1945, by States," American Fertilizer (1944); M. A. Anderson et al., An Appraisal of Factors Affecting the Acceptance and Use of Fertilizer in Iowa, 1953, Special Report No. 16, (Ames: Iowa Agricultural Experiment Station, 1956).

[2]Zvi Griliches, "The Demand for Fertilizer: An Economic Interpretation of a Technical Change," Journal of Farm Economics, Vol. 15, No. 3 (August, 1958), pp. 591-607.

relationship used in this study was the aggregate annual fertilizer consumption per acre in the United States regressed against a ratio of fertilizer price to prices received by farmers and fertilizer consumption lagged one year in logarithms over a 46 year period.

In a study of fertilizer usage in Japan from 1883 to 1937, 27 percent of the increased fertilizer use per land unit was related to a lowering of the real fertilizer price.[1] Another Asian fertilizer study found no relationship between price and consumption, but did find a correlation of fertilizer to water supply and farm size.[2]

Analysis of fertilizer use in Brazil has been almost completely limited to the description of price and quantity changes.[3] Normally, projections of fertilizer consumption have been based on past annual increases and changes in cultivated areas.[4] One

[1]Yujiro Hayami, "Demand for Fertilizer in the Course of Japanese Agriculture Development," Journal of Farm Economics, Vol. 46, No. 4 (November, 1964), pp. 766-79.

[2]Brook A. Greene, "Use of Fertilizer in Amphoe Manorom, Changwat Chainet, Thailand-1967-1968", Occasional Paper No. 36 (Cornell: Dept. of Agricultural Economics, Cornell University, 1970), p. 40.

[3]J. B. Costa, op. cit., pp. 5-6.

[4]Agency for International Development, "Brazil--Food Production Loan No. 2," (unpublished proposal in USAID files, Washington, D. C., 1966), pp. 27-33.

analysis of fertilizer use explained 50-60 percent of the variance in fertilizer imports by changes in the area of wheat and of rice in Rio Grande do Sul.[1] Various price ratios were included in the analysis, but no significant relationship was found. Major efforts to decrease fertilizer prices however, have been based on the assumption that decreases in fertilizer prices would increase the usage of fertilizer and therefore crop production. AID has granted or proposed $70 million of fertilizer import loans and the Brazilian government has granted import exchange rates subsidies of up to 46 percent, in addition to the special credit programs, for the purpose of decreasing real fertilizer cost to the farmer. Unfortunately, no research has substantiated the effect of the price subsidies. Presently, there is no knowledge of the proportion of increases in fertilizer usage which can be attributed to price policy or any other of the factors which may influence the utilization of fertilizer. This study analyzes only one factor in the demand equation, the value of the marginal product, although these estimates are compared to current fertilizer prices.

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[1]Knight, op. cit., pp. 168-71.

Demand for Fertilizer

Productivity

Analysis of the marginal product of fertilizer is central to the study of the economics of fertilizer utilization. Fertilizers are generally considered to be one of the purchased inputs that have marked impact on raising yields per acre and profitability of output. The return to fertilization has been estimated to be US$ 2.50 for each dollar spent for fertilizer in the United States.[1] Another study on fertilizer consumption assumed that increases of 20 to 40 percent in fertilizer use in Latin America would yield a 25 percent increase in production.[2]

The response to fertilization in Brazil has been documented in both formal experiments and informal observations, although the majority of these reports has not been designed to facilitate the process of making economic recommendations. This problem is

[1]Estimates of the U. S. Department of Agriculture as quoted by Montague Yudelman, Agricultural Development in Latin America: Current Status and Prospects, (Washington: Inter-American Development Bank, 1966), p. 52.

[2]Estimates of a FAO/CEPAL/BID study as quoted by Ibid, p.

emphasized in the following statement.[1]

> "Recently, we worked on a research project to analyze the increase in production and use of fertilizer in Brazil, ---. It was not difficult to gather 400 studies and experiments with fertilizer elements isolated or combined, but it was practically impossible to determine some idea of application levels given price information. This demonstrates the lack of suitability of the studies for economic interpretation."

This conclusion is shared by Rice who states:[2]

> "It is appalling how little research there is has been on the profitability of inputs and how few reliable reports on the subject can be found in most of Latin America."

The search for research reporting consistent high crop response to fertilizers yielded very few examples. An informal study of Operation Armadillo in Rio Grande do Sul reported that large increases in the usage of lime (5 to 6 tons per acre) and phosphate (400 to 500 pounds per acre) tripled the yield of soybeans and wheat. Low levels of lime and fertilizer previously used in the area had yielded almost no response, thus the author concluded that "until the early 1960's the economists and some soil specailists were so busy emphasizing efficient use of lime and fertilizer that they never

[1]Dr. Vitor Pellegrini, Comments on "Pesquisas Fundamentais Para Acelerar O Desenvolvimento Economico", paper by G. Edward Schuh, ANAIS IV, Reuniao da Socidade Brasileira de Economistas Rurais (Sao Paulo, 1966).

[2]E. B. Rice, Extension in the Andes: An Evaluation of Official U.S. Assistence to Agricultural Extension Services in Central and South America, AID Evaluation Paper 3A, (Washington: AID, 1971), p. 175.

realized the importance of sufficient use."[1]

The predecessor of Operation Armadillo was not as successful.[2] This project in the municipio of Ibiruba, Rio Grande do Sul, had placed emphasis only on soil testing, fertilizer and lime application and credit. Analysis of productivity changes between borrowers (fertilizer users) and non borrowers (non fertilizer users) revealed no significant differences in yields. The reasons given for these results were improper timing of fertilizer application, rainfall and insect problems.

A study of the response of cotton yields to fertilizers under experimental conditions in Sao Paulo found high responses to all nutrients when the initial levels of these nut rients were very low. When the natural levels of the nutrients in the soil were relatively high, however, the application of nitrogen, phosphate or potash

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[1]Carroll P. Streeter, "Operation Armadillo: A State at the Southern tip of Brazil undergoes a Transformation of Its Agriculture", (unpublished manuscript, Rockefeller Foundation, February, 1970), p. 9.

[2]Bernard Erven and Norman Rask, "Credit Infusion As a Development Strategy--The Ibiruba Pilot Project in Southern Brazil", (unpublished paper presented at the Seminar on Small Farmer Development Strategies, Sponsered by The Agricultural Development Council and The Ohio State University, Columbus, Ohio, 1971), p. 13.

decreased production.[1] Significant response of corn yield to nitrogen and phosphate was also found in Minas Gerais.[2] These conclusions are generally supported by soil scientists in their public statements. Fertilizer is claimed to yield production increases of two to ten times greater than the national average yield in experiments. (Table 5).

TABLE 5.--Summary of crop Response to fertilizer, Brazil

Crop	National Average Yield (tons/ha.)	Experimental Yield (tons/ha.)	Practical Possible (tons/ha.)
Beans	0.6	2.5	1.5
Coffee	0.4	2.0	1.0
Corn	1.3	15.0	4.0
Cotton	0.5	3.0	1.5
Soybeans	1.2	3.0	2.0
Sugar Cane	46.3	200.0	100.0
Rice	1.5	6.0	3.0
Wheat	0.8	3.0	2.0

Source: E. Malavolta, "Fertilizer Policy in the Developing Countries - The Case of Brazil", (unpublished paper, Piracicaba: Escola Superior da Agricultura "Luiz de Queiroz", undated), p. 6.

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[1] M. G. Fuzatto, Estudo Tecnico-Economico da Adubacao do Algodoeiro no Estado de Sao Paulo (Campinas: Instituto Agromonico de Campinas, 1970), p. 15.

[2] F. A. Santos and A. M. L. Neptune, "Adubacao de Milho no Municipio De Oliveira, Estado De Minas Gerais," ANAIS (Piracicaba: Escola Superior da Agricultura Luiz De Queiroz, Vol. XXVI, 1969), pp. 203-208.

Insignificant response to fertilizer was reported in a Rio Grande do Sul study and also in a study of fertilizer use in Northeastern Brazil. Non experimental farm data provided the base for the Rio Grande study in which the total value of fertilizer and other inputs were regressed against the total value of crop production.[1] The analysis of fertilizer use in the Northeast was based on a mixture of experimental results and general knowledge of area soil scientists.[2] The author used budgeting techniques to analyze the response of several crops to fertilization. Sugar cane was the only crop in the area for which fertilization increased returns per hectare. Yields would have to increase 105 percent for edible beans, 400 percent for corn and 120 percent for cotton over present levels in order to profitably apply fertilizer valued at Cr$ 35.00 per hectare. The author concluded that fertilizer would be a poor investment for most farmers in the Northeast

[1] Akram M. Steitieh, "An Analysis of Input Productivity and Productivity Change on Crop Enterprise in Southern Brazil" (unpublished Ph. D. dissertation, The Chio State University, 1971), pp. 42-53.

[2] K. D. Frederick, "Agricultural Development in the Brazilian Northeast", (unpublished paper in USAID Rio files, Rio de Janeiro, December, 1970), pp. 14-27.

Most of the research on fertilizer use in Brazil has yielded mixed results. A comprehensive 1964 review of fertilizer experiments in Brazil revealed positive responses to phosphate and potash (Table 6).[1] Nitrogen did not yield significant increases in crop yields in

TABLE 6.--Summary of fertilizer experiments in Sao Paulo reported by Agri-Research, Inc., 1964

Crop	Nutrient	Application (kg/ha)	Crop Response % increase	Crop Response kg/ha	Net[a] Revenue
Corn	Nitrogen	25	26	400	+
		60	0	0	-
		60	14	303	+
		80	35	...	..
	Phosphate	50	50	800	+
		90	25	600	+
	Potash	90	47	1700	+
Cotton	Nitrogen	60	0	0	-
		60	24	250	+
		120	11	140	-
	Phosphate	40	21	240	+
		90	24	250	+
	Potash	40	64	390	+
		90	12	170	+
		90	230	1600	+
		120	92	780	+
Rice	Phosphate	80	97	960	+
Soybeans	Nitrogen	200	21	230	-
	Phosphate	80	39	300	+
		90	25	286	+

[a]Based on 1964 prices in Sao Paulo.

Source: Agri-Research, Estudo Tecnico-Economico Sobre A Exequibilidade de Aumento Na Fabricacao e Uso de Fertilizantes, Calcario e Sais Minerais No Brasil (Rio de Janeiro: AID, 1964), pp. 65-185.

[1]Agri-Research, Inc. op. cit., pp. 124-61.

all experiments. Similarly, estimates of changes in net return due to fertilizer application were positive for phosphate and potash in all cases, however only about half the nitrogen experiments yielded positive net returns.

Analyses of fertilizer experiments with corn in Sao Paulo included fifty observations during four years.[1] Only nitrogen application was found to be economically profitable, however there was a large variation in the optimum levels of application.

Quadratic equations were used to estimate the response of yield to fertilizer in Rio Grande do Sul and significant coefficients were found for rice, wheat and corn with respect to nitrogen, phosphate and lime.[2] The responseswere at low levels, however, leading to zero optimum application levels under several of the hypothesized price conditions. Even under conditions of perfect knowledge, optimum nitrogen application was approximately 30 kg/ha. on irrigated rice, 10 to 40 kg/ha. on wheat and 30 to 75 on cotton for the years 1960, 1965 and 1966. Optimum phosphate levels were 60 kg/ha. for irrigated rice, 100 to 140 kg/ha. for wheat and 0 kg/ha. for corn during the same period. No significant response to potash was found.

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[1]Sonia Vieira, et. al., Estudo Comparativo De Tres Funcoes Na Analise Econometrica De Experimentos De Adubacao, (Piracicaba: ESALQ-USP, 1971), p. 30.

[2]Peter T. Knight, op. cit., pp. 143-63.

An analysis of a credit project in Peru found that farmers in the program were using more chemical fertilizer after joining the program, however, estimated average yield levels for most crops financed with credit were less than the yield averages published for the same regions by a national statistical reporting service.[1] Twenty-seven fertilizer trials in one region in Mexico found yield increases from zero to 4.2 tons per hectare.[2] Yield response was reported to be very sensitive to soil conditions, rainfall distribution during the growing season and timing and method of application.

In summary, the results of fertilization research are inconclusive (Table 7). Contrary to popular assumption that fertilizer is a key to unlocking large increases in production in Brazil, this review suggests that more research is needed to determine why a nutrient may have a significant positive impact on crop yields in one case and be insignificant in another. This problem appears to be especially serious for the use of nitrogen.

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[1]Ronald L. Tinnermeier, "Supervised Credit and The Small Farmer", (a paper presented at the Seminar on Small Farmer Development Strategies, sponsered by The Agricultural Development Council and The Ohio State University, Columbus, Ohio, 1971), pp. 8-9.

[2]Delbert T. Myren, "The Puebla Project: A Developmental Strategy for Low Income Farmers", (a paper presented a the Seminar on Small Farmer Development Strategies sponsored by The Agricultural Development Council and the Ohio State University, Columbus, Ohio, 1971), pp. 14-24.

TABLE 7.--Summary of findings of analyses of response to fertilizer

Researcher	Location	Crop	Crop Response to: Nitrogen	Phosphate	Potash	Total
Agri-Research	Sao Paulo	Corn	±	+	+	
"		Cotton	±	+	+	
"		Rice		+		
"		Soybeans	+	0		
Akram	Rio Grande do Sul	All crops				0
Frederick	N.E. Brazil	Sugar cane	+	+	+	
"	"	Other crops	0	0	0	
Inst. Agron.	Sao Paulo	Cotton	±	±	±	
Knight	Rio Grande do Sul	Rice	+	+	0	
		Wheat	±	±	0	
		Corn	±	0	0	
Santos	Minas Gerais	Corn	+	+	0	
Streeter	Rio Grande do Sul	Soybeans		+		
		Wheat		+		
Vieira	Sao Paulo	Corn	+	0	0	

[a]Positive response to fertilizer is signified by +, insignificant or no response by 0 and mixed responses by ±.

Management

The farm manager normally supplies both the labor and the entrepreneural ability to the farm business. This entrepreneural ability has often been assumed to be the key to differences in productivity and rates of physical capital formation in agriculture.[1] Education and usage of information sources also have been found to be correlated with managerial ability and the rate of adoption of new technology.[2]

The quality of management determines all other aspects of the farm operation to a great extent. Yet, the problem of identifying and describing management has not been solved. Empirical analyses

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[1] G. L. Mathis and R. E. Bender, Managerial Perception and Success in Farming (Columbus; Dept. of Agricultural Education, The Ohio State University, 1966); Donald M. Sorenson, Capital Productivity and Management Performance in Small Farm Agriculture in Southern Brazil (Columbus: Agricultural Finance Center, The Ohio State University, 1968); Zvi Griliches, "Estimates of the Aggregate Agricultural Production from Cross-Sectional Data," Journal of Farm Economics, Vol. 45, No. 2, (May, 1963), pp. 419-25; E. A. Persons et. al., Investments in Education for Farmers, Research Report, (St. Paul: University of Minnesota, 1968), pp. 37-44; G. F. Patrick and L. M. Eisgruber, "The Impact of Managerial Ability and Capital Structure on Growth of the Farm Firm," American Journal of Agricultural Economics, Vol. 50, No. 3, (August, 1968), pp. 491-506.

[2] H. F. Lionberger, Adoption of New Ideas and Practices (Ames: The Iowa State University Press, 1960); N. S. Shetty, "Agricultural Innovations: Leaders and Laggard," Economic and Political Weekly, Vol. III, No. 33, (August 17, 1968), pp. 273-81.

of management have either used proxy variables such as education, technology adoption or experience, or assumed different technical input-output coefficients to represent differences in management ability.[1] A few studies have analyzed the decision processes of management.[2] None of these approaches have been completely satisfactory and the process of investigating the characteristics and the effects of different levels of management ability is far from complete.

Credit Policy

An informal system of cooperatives, private firms and industries, and savings and loans associations provided credit to agriculture previous the creation of an official credit agency in the Bank of Brazil. There are however no records of the amount or terms of this credit. Agricultural credit granted by the Carteira da

[1] J. J. C. Engler, "Alternative Enterprise Combinations Under Various Price Policies on Wheat and Cattle Farms in Southern Brazil" (unpublished Ph. D. dissertation, Dept. of Agricultural Economics and Rural Sociology, The Ohio State University, 1971), pp. 47-72; D. M. Sorenson, op. cit., pp. 117-49; and G. F. Patrick and L. M. Eisgruber, op. cit., p. 499.

[2] G. L. Johnson et. al., A Study of Managerial Processes of Midwestern Farmers (Ames: Iowa State University Press, 1961), p. 172; E. O. Heady et al., Uncertainty Expectations and Investment Decisions for a Sample of Central Iowa Farmers, Bulletin 447, (Ames: Iowa Agricultural Experiment Station, 1957).

Credito Agricola e Industrial of the Bank of Brazil increased very slowly throughout the fifties.[1] In 1959, the real value of their agricultural production loans reached a peak which was not equalled again until 1967.[2] Inflation, up to 85 percent annually, eroded the value of currency more rapidly than the monetary amount of agricultural credit was increased. Credit was granted at 7 to 10 percent nominal rates of interest until 1960. From 1961 to 1965, nominal interest rates varied from 12 to 17 percent annually for bank credit, however non-bank rates varied according to the rate of inflation.

Credit for fertilizer purchases was put under a new program in 1966, FUNFERTIL.[3] The purpose of this fund was to finance the full value of the interest and administrative costs of fertilizer loans for food crops. The program financed the purchase of 18,000 tons of fertilizer in Sao Paulo during 1966, 10 percent of total consumption.[4]

[1]Ralph Von Gersdorff, "Agricultural Credit Problems in Brazil," The Indian Journal of Economics, Vol. XVI, No. 161, (October, 1960), pp. 151-71.

[2]See Appendix E for national credit statistics.

[4]Instituto De Economia Agricola, Desenvolvimento Da Agricultura Paulista, (Sao Paulo: Secretaria Da Agricultura, March, 1971), p. 143.

[3]Fundo de Estimulo Financeiro ao Uso de Fertilizantes e Suplementos Minerais.

In 1968, the volume of FUNFERTIL credit granted reached its highest level when 49 percent of Sao Paulo consumption and 75 percent of the national fertilizer consumption was financed by FUNFERTIL.[1]

FUNDAG replaced FUNFERTIL on August 1, 1970. This fund subsidizes credit for "modern inputs" including fertilizer.[2] Farmers will pay a 7 percent annual interest charge as compared to other agricultural bank credit with interest rates of 9 to 17 percent and credit from nonbank sources which charge 24 to 36 percent.[3] A 1968 law now requires all banks to loan 10 percent of their deposits for agricultural purposes or return them to the central bank where they will be loaned to agriculture via the Bank of Brazil.[4]

The lack of agricultural credit at reasonable interest rates is often assumed to be a limiting factor in the adoption of new technology. This assumption has been the basis for Brazil's

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[1] Costa, op. cit., p. 7.

[2] "Modern Inputs" include fertilizer, lime, livestock mineral and protein supplements, improved seed, artificial insemination and agricultural chemicals.

[3] The rate of inflation in 1969-70 was about 20 percent.

[4] Judith Tendler, "Agricultural Credit in Brazil", (unpublished report to USAID Mission, Brazil, October, 1969), p. 15 and p. 81.

FUNFERTIL and FUNDAG programs and also their control of interest rates for all agricultural bank credit. The discussion of credit can be divided into two parts; the change in the volume of credit available to agriculture and the cost of the credit to the borrower.

Several economists have stated that the lack of credit is a major restriction to technological change and investment in the agricultural sector.[1] The lack of profitable investments, not the lack of credit is restricting capital formation according to other researchers.[2] Recent studies however, have shown that investment is primarily a function of access to credit.[3] In Southern Brazil, the transformation of farms from range livestock to crops increased

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[1] Ragnar Nurkse, Problems of Capital Formation in Underdeveloped Countries and Patterns of Trade and Development (New York: Oxford University Press, 1967), pp. 4-5; M. L. Dantwala "Institutional Credit in Subsistence Agriculture," International Journal of Agrarian Affairs, Vol. V, No. 1, (December, 1966), p. 52; Clyde Mitchell and Jacob Schatan, op. cit., p. 52.

[2] T. W. Schultz, op. cit., pp. 3-23; Vernon Ruttan, "Southeast Asian Agricultural Markets," Agricultural Cooperatives and Markets in Developing Countries, ed. R. K. Anschel, (New York: Frederick A. Praeger, Inc., 1969), pp. 79-106; W. D. Hopper, "Investment in Agriculture: The Essentials for Payoff," Strategy For the Conquest of Hungar, Proceeds of a Symposium convened by the Rockefeller Foundation, (New York: The Rockefeller Foundation, 1968), p. 197.

[3] M. F. Long, "Why Peasant Farmers Borrow," American Journal of Agric. Econ., Vol. 60, No. 4, (Nov., 1968), pp. 991-1008; C. V. Narasimhacher, "Indebtedness and the Level of Development in Some South Indian Villages," Agricultural Situation in India, Vol. 21, No. 1, (April, 1966).

cash operating costs by sevenfold and the use of credit by two-hundredfold.[1]

The volume of institutional credit for agriculture in Brazil increased at a 17 percent annual rate from 1960 to 1968. In 1968, the ratio of institutional credit to the value of agricultural production was .37 in Brazil.[2] This compares favorably with the ratio of .53 in the United States and is equal to that of Taiwan. Although it appears that the volume of institutional credit may be sufficient to support high rates of technological change and capital formation, the distribution of credit is biased toward large farms.[3] One study of fertilizer credit in Brazil revealed that 20 percent of the farmers in a subsidized credit program received two-thirds of the credit.[4]

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[1] B. P. Rao and Norman Rask, "Modernization of Developing Agriculture: A Brazilian Experience" (unpublished manuscript, The Ohio State University, Columbus, 1970), p. 9.

[2] Dale W. Adams, "Agricultural Credit in Latin America: A Critical Review of External Funding Policy," American Journal of Agricultural Economics, Vol. 53, No. 2, (May, 1971), p. 170.

[3] Judith Tendler, op. cit. p.37; B. P. Rao, "The Economics of Agricultural Credit-Use in Southern Brazil" (unpublished Ph. D. dissertation, Dept. of Agricultural Economics, The Ohio State University), p. 67; and C. Mitchell and J. Schatan, op. cit., p. 52.

[4] D. M. Sorenson and others, An Evaluation of the CNCR Fertilizer Loan Program in Brazil, AFC Research Report 118, (Columbus: The Agricultural Finance Center, The Ohio State University, 1967), p. 22.

Another study found that 5 percent of a sample of 392 farmers absorbed 72 percent of the increase in credit from 1965 to 1968.[1] Larger farms normally present fewer lending risks, and larger loans have lower administrative costs per unit of money lent, therefore it is logical from the viewpoint of the banks that larger farms would receive the majority of the credit. Part of the reason for unequal credit distribution however, can be found in the assumption made by a Brazilian credit official.[2]

> Thus 89 percent of the farmers only had the capacity to take 11 percent of the credit while 89 percent of the value fit the 11 percent of the enterprenuers with larger establishments and technical needs.

Interest rates for institutional credit are quite often negative in real terms, i.e., the inflation rate is higher than the nominal interest charge in developing countries. It has been assumed that low or negative interest rates are necessary to stimulate technological change. These low rates, nevertheless, may be a major factor in causing the unequal distribution of institutional credit. When the

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[1]Dale Adams, William Simpson and Joseph Tommy, Credit Brazil, CFP Research Note No. 8, (Columbus: Dept. of Agricultural Economics and Rural Sociology, The Ohio State University, 1970), p. 5.

[2]Dr. Alexandre Caminha, Comment on a paper, "O Papel do Credit no Desenvolvimento da Agricultura" by J. H. Atkinson, ANAIS: IV Reuniao da Sociedade Brasileira de Economistas Rurais, (Sao Paulo, 1966), p. 79.

interest rate is no longer a rationing agent, factors such as personal friendship and the internal financial interest of banks may be the allocative factors. A recent study found the return to additional credit to be substantially higher on small farms than on large farms, implying an inefficient allocation of credit.[1] An evaluation of subsidized credit programs found that because of negative interest rates the stock of capital had suffered a net loss of 47 percent in three years.[2] The value of the loans outstanding decreased to one-quarter of the value in the initial year. In addition to presenting the rapid decrease in value of credit, the author concludes "the prevalent theme in Brazil that the farmers will not absorb credit with high interest rates appears to be based on the large land owners not on family farms."[3]

Informal credit, i.e., from businesses and individuals, has

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[1] B. P. Rao, op. cit., p. 149.

[2] Banco Interamericano De Desarrello, "Evaluacion De l Programa Do Credito Rural Educative Em Brazil", (preliminary report, 1971), p. 64

[3] Ibid., p. 67.

been assumed to carry extremely high interest rates.[1] Studies in Asia have found that a very high proportion of agricultural credit originates from informal sources.[2] South American studies indicate that informal credit accounts for less than one half of the amount borrowed.[3] Two of these studies found that a substantial number of informal loans had no interest charges and average interest rates were not excessive when risk and inflation rates were considered.[4] A Colombian study shows interest rates varying from 24 to 96 percent however the high rate was for very short periods of

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[1]Ralph Von Gersdorff, op. cit., pp. 151-71; C. R. Wharton, Jr., "The Infrastructure for Agricultural Growth," Agricultural Development and Economic Growth, ed. H. M. Southworth and B. R. Johnston (Ithaca: Cornell University Press, 1967), p. 126.

[2]Reserve Bank of India, Rural Credit Follow-Up Survey, 1959-60--General Review Report (Bombay: Reserve Bank of India, 1962), pp. 29-31.

[3]Bernard Lee Erven, "An Economic Analysis of Agricultural Credit and Policy Problems, Rio Grande do Sul" (unpublished Ph. D. dissertation, Dept. of Agricultural Economics, University of Wisconsin, 1967), p. 101; B. P. Rao, op. cit., p. 74; Luis Eduardo Montero, "The Allocation of Agricultural Credit in Columbia" (unpublished Master's thesis, Dept. of Agricultural Economics and Rural Sociology, The Ohio State University, 1969), p. 67; C. T. Nisbet, "Interest Rates and Imperfect Competition in the Informal Credit Market of Rural Chile," Economic Development and Cultural Change, Vol. 16, No. 1, (October, 1967), pp. 73-90; J. N. Stitzlein, The Characteristics and Significance of the Non-Institutional Credit Market in Rural Ecuador, AFC Research Publication No. 117, (Columbus: The Agricultural Finance Center, The Ohio State University, 1967), p. 29.

[4]C. T. Nisbet, op. cit., pp. 73-90; J. N. Stitzlein, op. cit., p. 29.

two to three weeks.[1] This survey of farmers reported that the majority of farmers preferred to borrow from moneylenders rather than banks even though interest rates were higher. The rationale given was the simple procedure of obtaining non-bank credit, minimum lag time between request and obtaining funds, and the requirement of banks that the borrower have time or demand deposits in the bank.

Studies of rural credit systems have increased rapidly in number during recent years, yet few firm conclusions can be made. The question of a credit or technology bottleneck appears to vary according to specific situations. The impact of fertilization on farm income, and credit requirements require further research in order that national fertilizer policies may be evaluated with respect their total effect. The volume of agricultural credit is rising rapidly, but distribution of credit and the level of interest rates appear to be far from ideal. The importance of informal credit and its relationship to the formal credit market has not been clarified.

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[1] C. T. Nisbet, "Moneylending in Rural Areas of Latin America: Some Examples from Colombia," The American Journal of Economics and Sociology, Vol. 30, No. 1, (January, 1971), p. 74.

Summary

The Brazilian government has made several policy changes aimed at modernizing agriculture and increasing production, especially of food crops, during recent years. A major effort was made to stimulate fertilizer use by adjusting real fertilizer prices and furnishing low cost credit for fertilizer purchases. As a result, fertilizer utilization has increased at a rapid rate in the past few years. The fertilizer distribution system has kept pace with demand and has increased the number of services offered to the farmer.

The Brazilian fertilizer situation is not without problems however, as the absolute increases in fertilizer use have been concentrated in the South and Center areas. Vast numbers of small farmers, especially in the Northeast, have not participated in the expansion. Domestic production of fertilizer has lagged far behind consumption. The lack of natural resources and rapid technological changes in production techniques have been the major problems of the Brazilian fertilizer industry.

In this review of the factors affecting fertilizer usage and the effect of its' utilization, several of the topics were not covered in depth. The objective was to cover the major issues and to reveal the complexity of the interaction of various factors influencing fertilizer demand. The major conclusion of this review is that the present

level of knowledge is limited and not sufficient for adequately informed decision-making. The unanswered questions with regard to fertilizer use include the following:

1. Are the present varieties of crops responsive to fertilizer?
2. Is the crop response to fertilizer equal on farmer's fields and experimental plots?
3. What is the price elasticity of demand for fertilizer?
4. Do increases in product prices have the same effect on demand as decreases in fertilizer prices?
5. What is the distribution of formal fertilizer credit?
6. What is the interest rate elasticity of demand for fertilizer credit?
7. Are private marketing firms capable to meet rapidly increasing demands for fertilizer?
8. Are there major differences in prices for identical fertilizers?
9. Does management and extension have an effect on the rate of fertilizer adoption and application?
10. Does the usage of information by the farmer have an effect on the rate of fertilizer adoption and application?
11. What is the effect of fertilizer usage on the farm capital structure?
12. Does fertilizer consumption increase rates of capital formation?
13. What is the national benefit/cost ratio of fertilizer policies?

This study concentrates on determining the economic profitability of fertilizer use at the farm level.

CHAPTER III

DESCRIPTION OF AREA AND SAMPLE

The purposes of this chapter are to provide descriptive background on the area studied, detail the sampling procedure, and present a general description of the farms sampled.

Area Description

Farms interviewed for the study were located in the northern part of the state of Sao Paulo. This state is the most populous in Brazil with about one-fifth of the country's total population in only 3 percent of the total area. By most measures Sao Paulo is also the economic center of the country, producing over one-third of Brazil's total gross national product. The state contains a majority of Brazil's industrial base, but also has substantial agriculture. About 15 percent of the state's gross national product originates from agriculture. Agriculture in the state is highly commercial, price sensitive, dynamic, progressive, and the most important overall user of fertilizer in Brazil. Prior to 1930, Sao Paulo was a major producer of coffee and livestock. Since then production has been substantially diversified. Corn, peanuts, sugar cane, rice, soybeans, intensive truck crops, dairy, poultry and commercial fruit production have all expanded in importance. The extension service, marketing

system, and rural transportation in Sao Paulo are among the best in the country.[1]

Ribeirao Preto, the region within the state where interviewing was done, is a major producer of agricultural products. It includes 30 thousand farms totaling 3.6 million hectares in 80 municipios. This region is a major producer of cotton, oranges, sugar cane, corn, rice, soybeans and some truck crops. Much of the land in this region is presently being used for crops, but some land clearing is still being done. As can be noted in Table 8, Ribeirao Preto has a production pattern which is in many respects quite representative of agriculture in the state.

This area was selected because of the large number of crops grown, the high degree of commercialization, extensive fertilizer and institutional credit use, the progressive nature of the farmers, and the rather complete rural infrastructure available in the area. Because of these conditions, it was thought that farmers in the area would be well into the fertilizer adoption process and thus be most suitable for production function analysis.

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[1]A detailed description and evaluation of the agricultural sector in Sao Paulo is given in Instituto De Economia Agricola, Desenvolvimento Da Agricultura Paulista, (Sao Paulo: Secretaria Da Agricultura, March, 1971).

TABLE 8.--Area and Production of Selected Agricultural Products in the State of Sao Paulo and Ribeirao Preto Region, 1970

Crops	Sao Paulo Area (ha.)	Sao Paulo Production (tons)	Sao Paulo Rank within Brazil in Area[a]	Ribeirao Preto Area (ha.)	Ribeirao Preto Production (tons)	Ribeirao Preto Rank within Sao Paulo in Area[b]
Beans	230,933	128,237	7	16,238	5,820	4
Coffee	762,325	732,000	2	64,400	33,000	3
Corn	1,317,595	2,114,931	3	271,863	390,000	2
Cotton	469,767	551,493	1	76,690	115,050	1
Lemons	1,930*	2,570**	-	638	963,000**	6
Peanuts	479,193	565,772	1	33,928	40,700	3
Oranges	82,996	6,305,544	1	13,954*	585,320	1
Rice	709,017	774,097	4	181,330	132,000	2
Soybeans	47,121	61,010	3	42,471	54,600	1
Sugar Cane	495,704	25,087,374	1	197,327	9,354,000	1
Tomatoes	18,400	381,000	1	9,183	126,500	1

*1000 plants/hectare.

**Boxes of 40 kgm.

Source: (1) Anuario Estatistico Do Brasil, Instituto Brasileiro de Estatistico, (IBGE), Rio de Janeiro, 1970; and (2) Anuario Estatistico, Sao Paulo, Secretaria De Economia e Planejamento, Departmento de Estatistico, Sao Paulo, 1970.

[a]There are 22 states within Brazil.

[b]There are nine regions within the state.

Ten municipios were selected as being representative of the region on the basis of statistical data and conferences with the regional extension personnel. These municipios represented areas which were primarily specialized in annual crops, perennial crops, livestock and general farms. Each sample farm and alternates were randomly chosen from the land rolls of IBRA (Instituto Brasileiro de Reforma Agraria) and subjected to the criteria that: (1) more than 50 percent of the owned land was cultivated; (2) more than 50 percent of the cultivated land was devoted to the production of one of the enterprise specialities; and (3) more than 50 percent of the land was owner-operated. Based on these sampling criteria, 383 interviews were carried out during July, 1970.

Three municipios (Guaira, Jardinapolis and Sales de Oliveira) were chosen because the majority of the farmers there specialized in the production of annual crops. These municipios contained 130 of the 174 farms in the total sample which were specialized in annual crops.

Guaira (69 interviews with crop farmers) was settled in about 1900 by ranchers. Coffee production was introduced in the 1920's and it was not until 1948 that the agricultural sector began changing to annual crop production. Approximately two-third of the population of 27,000 reside in the one town in the municipio, however 80 percent

of the value of the gross product of the municipio originates from agriculture.

The municipios of Jardinapolis and Sales de Oliveira (65 interviews with crop farmers) are located about one hundred miles from Guaira and adjoining the municipio of Ribeirao Preto, the major commercial center of the region. Like Guaira, the majority of the population lives in the center town, but derives over 50 percent of their income from agriculture. These municipios do contain some perennial crops and livestock whereas Guaira has no perennial crop production.

The remaining forty annual crop farmers interviewed were scattered throughout the other seven municipios in the region.[1]

The climate of the region is classified a moderate tropical with dry winters (June-August) and humid wet summers. The average annual rainfall is 1100 to 1700 mm. The 1969/70 agricultural year (August 1, 1969 to July 31, 1970) received an average amount of rainfall which was distributed during the year in normal fashion (Table 9). The critical rainfall periods are November to January (planting) and February to April (growth).

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[1]Further description of sampling procedure and characteristics can be found in Kelso Wessel and William Nelson

TABLE 9.--Rainfall in the Ribeirao Preto Region 1968-1970

Months	Precipatation in mm.[a] 1968	1969	1970
August 1 - October 31	16.1-213[b]	103-330	.....
November 1 - January 31	.....	317-646	325-552
February 1 - April 30	.....	93-420	305-441
May 1 - June 30[c]	.....	10-32	25-80

[a]Minimum and maximum values from five location within the region.

[b]Includes only September and October.

[c]Data were not available for July.

Source: Instituto de Economia Agricola, "Estatisticas Agricolas", (Divisao de Levantamentos e Analises Estatisticas, Sao Paulo, various issues 1968 - 1971).

The major soil type in the region is terra roxa legitima (legitimate red earth) which covers about 50 percent of the area. Terra roxa and the other soils of the region are mineral soils, normally acidic and contain substantial amounts of iron and bauxite. They are conglomerate soils with good drainage characteristics. They are very productive soils which are considered among the best in Brazil and can support high production levels of a diversity of agricultural products.

The average yields of crops during 1969/70 were higher than the five year average in nearly all cases (Table 10). This may be due

TABLE 10.--Average yields of selected annual crops for 1966-70 and 1969/70

Crops	Average for 1966-1970		1969/70	
	Guaira	Jardinapolis	Guaira	Jardinapolis
Corn (60kg/alq)	100.61	76.04	107.88	108.81
Rice (60 kg/alq)	45.87	38.74	61.89	76.70
Cotton (15kg/alq)	146.62	193.17	223.05	190.34
Soybeans (60 kg/alq)	58.87	60.81	67.25	52.12

Source: Instituto Economia, (unpublished information, Sao Paulo, 1966-1970) and yield data of sample farms.

partially to the selected sample of specialized crop farms, but it does indicate a good production year. These favorable conditions should result in a higher than normal response to fertilizer.

Sample Farms

The farms analyzed in this study are 174 of 383 farms which were interviewed in the Ribeirao Preto area in July, 1970.[1] Farms included in this study are all farms which were classified as

specialized annual crop (more than 50% of cultivated land in one crop and more than 50% of total land in crops) or as general crop farms (more than 50% of total land in crops). The basic-size-type-location distribution (Table II) shows that the largest number of

TABLE II. --Distribution of sample farms by size, type and location

Size (hectares)	Number of Farms					
	Type		Location			Total
	Spec. Crop	Gen. Crop	Guaira	Jard.-Sales	Other	
10-30	16	22	13	21	4	38
31-200	36	53	33	34	22	89
201-3000	22	25	23	10	14	47
Total	74	100	69	65	40	174

farms are in the middle size group, and are not specialized in the production of any one crop.

Owner-operator was the major tenure arrangement among the sample farms (Table 1a). There was a much higher percentage of owner-operators among small farms (68%), however, than in the middle and large size groups (43%).

TABLE 12 --Tenure situation of sample farms by size, type and Location

Descriptive Factors	Number of Farms			
	Owner-Operator	Owner & rents to and/or from others	Partnership	Total
Size (ha.)				
(a) 10-30	26	4	8	38
(b) 31-200	43	31	15	89
(c) 201-3000	16	19	12	47
Type				
Spec. Crop	35	32	7	74
Gen. Crop	50	22	28	100
Location				
Guaira	38	24	7	69
Jard.-Sales	30	17	18	65
Other	17	13	10	40
Total	85	54	35	174

Corn is the most common crop in the area, and is grown on 151 of the 174 farms. Rice was produced by 110 farmers, cotton by 82 and soybeans by 40 farmers. Some farms in the sample also produced small amounts of coffee, sugar cane for cattle roughage, lemons, oranges, and pineapple. Nearly all farmers produced edible beans, but primarily for home consumption.

Only two of the sample farms did not apply fertilizer in the 1969/70 agricultural year (Table 13). Thirty-nine percent of the farms

TABLE 13.--Fertilizer use per farm by size, type and location of sample farms

Fertilizer Use Per Farm (metric tons)	Number of Farms								
	Size (ha)			Type		Location			Total
	10-30	31-200	201-3000	Spec. Crop	Gen. Crop	Guaira	Jard.-Sales	Other	
(1) 0	1		1	2		1		1	2
(2) 1-5	31	15		20	26	18	21	7	46
(3) 6-10	4	25		7	22	8	13	8	29
(4) 11-20	2	22	5	17	12	12	9	8	29
(5) 21-30		12	3	8	7	4	4	7	15
( ) 31-40		5	3	2	6	2	2	4	8
(7) 41-50		6	8	6	8	5	7	2	14
(8) 51-100		2	14	6	10	11	3	2	16
(9) 101-1000			13	5	8	7	5	1	13
(10) 1001-10,000		2		1	1	1	1		2
Total No. of Farms	38	89	47	74	100	69	65	40	174

bought more than 30 tons of fertilizer, however, over 70 percent operated more than 30 hectares of land. There does not appear to be any major differences in fertilizer use patterns based on location or farm type.

Actual fertilizer use as a percent of the minimum recommended quantity is higher than the a-priori expectations. Previous studies indicated average use levels in the range of 25 to 75 kg/alqueire, however, an average of nearly 200 kg/alqueire is used in this region The total fertilizer use in cotton and soybean production is 100 and 140 percent of minimun recommendations respectively. Rice and corn land receive only 60 percent of the minimum recommended nutrients (Table 14).

Nitrogen application is low relative to minimum recommendations (24 to 94 percent) and in absolute terms. Approximately 350 kg. of nitrogen per alqueire is used on corn land in Ohio, for example, as compared to 34 kg in the Ribeirao Preto region.[1]

The use of phosphate varies from 52 to 127 percent of minimum recommended application. Phosphate application is also low relative to Ohio, for example, the average use on corn in Ohio is approximately 150 kg. per alqueire while in the sample region it is 80 kg per alqueire.

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[1] Based on 125 to 150 pounds of nitrogen per acre.

TABLE 4. -- Comparison of fertilizer recommendations to actual use by farmers in the Ribeirao Preto Region, 1969/70

Fertilizer and Crop	Recommendation[a] (kg. /alq.)[b]	Actual Use (kg. /alq.)	Actual Use as % of Minimum Recommendation
Cotton			
(1) Nitrogen	78-192	43.96	56%
(2) Phosphate	144-288	183.51	127%
(3) Potash	115-288	114.47	100%
(4) Total	335-768	341.95	102%
Rice			
(1) Nitrogen	30-77	16.84	56%
(2) Phosphate	144-230	74.47	52%
(3) Potash	30-150	31.79	106%
(4) Total	204-457	123.11	60%
Corn			
(1) Nitrogen	142-164	34.10	24%
(2) Phosphate	108-216	80.47	74%
(3) Potash	22-44	51.48	234%
(4) Total	272-424	166.07	61%
Soybeans			
(1) Nitrogen	22-44	20.65	94%
(2) Phosphate	108-144	111.67	103%
(3) Potash	22-44	80.00	364%
(4) Total	152-232	212.32	140%
All Crops			
(1) Nitrogen	83.60	30.14	36%
(2) Phosphate	126.05	111.86	89%
(3) Potassium	44.21	58.41	132%
(4) Total	253.42	199.41	79%

[a]Associacao Nacional para Difusao de Adubos, "Sugestoes Gerais De Adubacao, " (unpublished paper, Sao Paulo, 1970), p. 13.

[b]One alqueire equals 2.42 hectares or 5.98 acres and one kilogram equals 2.2 pounds.

The use of potash is equal to or greater than the minimum recommendations for every crop, reaching a high of 364 percent of the recommended quantity on soybean land. The absolute level, however remains below the average use in Ohio in soybean production (80 versus 150 kg. /alq.).

About three-quarters of the farmers used credit to purchase fertilizer, but less than half used bank credit (Table 15). The use of bank credit varied by size group. Only one-quarter of the small farmers used bank credit as compared to over one-half of the middle and large farms. Conversely, a higher percentage of small farmers obtained credit from cooperatives and businesses than the other two groups.

Farm type does not appear to influence credit use, however location does appear to be significant with respect to the Jardinopolis Sales de Oliveira area. Approximately one-third of the farms in this area used bank credit while more than half in the other two areas obtained bank credit. The farmers in the Jardinopolis-Sales de Oliveira area used much more business credit than the other areas, thereby compensating for the lower level of bank credit.

Indices of management ability and information use were constructed for use in the productivity analysis. Both are presented here, however only the management index is used in the

TABLE 15. --Credit use per operated hectare on sample farms by size, type and location

Credit Sources and Amounts	Number of Farms								
	(Size (ha)			Type		Location			Total
	10-30	31-200	201-3000	Spec. Crop	Gen. Crop	Guaira	Jard.-Sales	Other	
Bank Credit (Cr$ / ha.)									
(1) 0	28	42	24	38	56	33	42	19	94
(2) 1-50		4	2	3	3	1	2	3	6
(3) 51-100		4	6	5	5	2	3	5	10
(4) 101-200	5	20	7	17	15	18	10	4	32
(5) 201-300	3	11	4	10	8	11	4	3	18
(6) 301-400	2	5	1		8	2	4	2	8
(7) 401-500		2	2	1	3	2		2	4
(8) 501-600		1	1	2					2
Coop. Credit (Cr$ / ha.)									
(1) 0	32	81	46	73	86	65	59	35	159
(2) 1-50	1	2			3		2	1	3
(3) 51-100	2	3		1	4	2	2	1	5
(4) 101-200	3	2	1		6	2	2	2	6
(5) 201-300		1			1			1	1
(6) 301-400									
(7) 401-500									
(8) 501-600									
Business Cre. (Cr$ / ha.)									
(1) 0	26	77	39	62	80	62	43	37	142
(2) 1-50	1	3	1	2	3	1	3	1	5
(3) 51-100	4	2	1	3	4		6	1	7
(4) 101-200	7	4	4	9	6	3	11	1	15
(5) 201-300		2	1	1	4	2	1		3
(6) 301-400		1	1	1	3	1	1		2
Total	30	89	47	74	100	69	65	40	174

productivity analysis as they are both attempts to measure management. (Table 16)

The management index is composed of weighted values of experience, education, use of insurance, farm records, credit, soil analysis and information sources and membership in an agricultural organization. The information index is made up of eleven different information sources, each weighted by their value as a source of agricultural information.[1]

The management and information indices were closely related, simple correlations of 0.74 to 0.82, and were distributed over the full range of possible values. Farm size appears to be positively related to the indices, and this is substantiated by simple correlation coefficients of 0.28 to 0.37.

The index of information does not appear to be affected by farm type or location except in the case of Guaira. Guaira is the most isolated of the municipios and is not served by a full-time agronomo.

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[1]See Appendix D for the method of calculating the indices.

TABLE 16. --Indices of management and information use of sample farms by size, type and location

Descriptive Factors	Number of Farms								
	Size (ha)			Type		Location			Total
	10-30	31-200	201-3000	Spec. Crop	Gen. Crop	Guaira	Jard.-Sales	Other	
Management Index I									
(1) 0-300	8	1	1	7	3	7	2	1	10
(2) 301-400	8	12		11	9	11	6	3	20
(3) 401-500	12	16	8	16	20	17	12	7	36
(4) 501-600	2	25	10	16	21	14	12	11	37
(5) 601-700	6	19	7	10	22	8	16	8	32
(6) 701-800	1	10	11	6	16	7	9	6	22
(7) 801-900	1	5	7	7	6	4	6	3	13
(8) 1000		1	3	1	3	1	2	1	4
Information Index I									
(1) 0-300	12	11	3	15	11	18	4	4	26
(2) 301-400	11	14	6	14	17	12	15	4	31
(3) 401-500	8	17	4	12	17	8	14	7	29
(4) 501-600	3	9	8	8	12	9	9	2	20
(5) 601-700	4	8	5	6	11	7	6	4	17
(6) 701-800		16	6	10	12	4	9	9	22
(7) 801-900		8	10	4	14	8	4	6	18
(8) 1000		6	5	5	6	3	4	4	11

CHAPTER IV

MODEL AND VARIABLE DESCRIPTION

The statistical models which will be used in the analysis of fertilizer are presented in first section of this chapter. Dependent and independent variables are listed and described in the second section and the estimated equations for each of the various subsamples are listed in the last portion of the chapter.

Statistical Model

A production function is a quantitive relationship between an output and one or more inputs. Mathematical forms used to represent this relationship include the polminial, the Cobb-Douglas (linear in logarithms), the Mitscherlich, the Spillman, the logistic, and the linear.[1] The Cobb-Douglas and the quadratic forms are used in

[1]See the following publications for a more complete discussion of these functions: David D. Mason, "Functional Models and Experimental Designs for Characterizing Response Curves and Surfaces," ed. E. L. Baum et. al., Economic Analysis of Fertilizer Use Data (Ames: Iowa State College Press, 1956), pp. 76-98; E. O. Heady et al., Crop Response Surfaces and Economic Optima in Fertilizer Use, Bulletin 424, (Ames: Iowa Agricultural Experiment Station, 1955); FAO, Statistics of Crop Responses to Fertilizers (Rome Food and Agricultural Organization of the United Nations, 1966), p. 112.

this analysis.

The Cobb-Douglas function may be generalized to:

$$Y = aX_1^b X_2^c \ldots\ldots X_n^n$$

The logarithmic form is

$$\log Y = \log a + b \log X_1 + c \log X_2 + \ldots\ n \log X_n$$

Where:

Y = Dependent variable (output)

a = level of the function

$X_1, X_2 \ldots X_n$ = independent variables (inputs)

$c, b, \ldots n$ = regression coefficients

The characteristics of the Cobb-Douglas function are: (1) elasticities of substitution equal to one; and (2) constant partial and total elasticities of production. Thus, the function can only exhibit increasing, decreasing or constant returns to scale. The regression coefficients are production elasticities from which marginal productivities can be derived in the following fashion

$$MP_i = AP_i\ (E_i)$$

where: MP_i = Marginal Product of input:

AP_i = Average Product of input:

E_i = Elasticity of Production of input:

The economic optimum level of an input is defined by the following

formula:

$$VMP_i = P_i$$

where: VMP_i = Value of the marginal product defined as the product price times the marginal product.

P_i = Price per unit of the input.

The quadratic equation can represent all theoretical regions of the production functions thus exhibiting ranges where the marginal product (MP) is greater than the average product (AP), where MP is less than the AP and positive and where MP is negative. The general form of the quadratic equation is:

$$Y = a + b_1X_1 + c_1X_1^2 + c_2X_2^2 + d_1X_1X_2 + \ldots d_nX_nX_m)$$

where

Y = Dependent variable

a = Level of function

b...n = Regression coefficients

$X_1 \ldots X_m$ = Independent variables

The value of the marginal product of an independent variable is calculated by multiplying the product price per unit times the marginal product which is the first derivative of the equation

$$MP = \frac{\partial Y}{\partial X_1} = + b_1 + c_1X_1 + d_1X_2$$

The statistical test used to determine the significance of the regression

coefficients is

$$t = \frac{bi}{S_{xi}}$$

where: t = Value of the t statistic

bi = Regression coefficient

S_x = Standard Error of the Regression Coefficient

The formula used to test the significance the regression equation:

$$F = \frac{SSreg.}{d.\ f.} \Big/ \frac{SS\ res.}{d.\ f.}$$

Where: SSreg = Sum of Squares Regression

SSres. = Sum of Squares Residual

d.f. = degrees of freedom

The statistical assumptions made are:

1. e_i is a random variable with a mean zero and variance σ^2 (unknown) which is normally distributed.

2. e_i - e_i-1 are uncorrelated, so that the covariance of e_i and e_i - 1 = 0.

Variable Description

Specification of variables used in the production function analysis is presented in two sections. The variables entering the individual crop analyses are presented first and is followed by a description of the variables entering the aggregate crop functions.

Twenty-five independent variables are included in the production functions. These are:

X_1 = Lime (tons/alq.)

X_2 = Nitrogen (kg. of N/alq.)

X_3 = Phosphate (kg of P_2O_5/alq.)

X_4 = Potash (kg. of K_2O/alq.)

X_5 = All Fertilizer ($X_2 + X_3 + X_4$)

X_6 = Total Labor (Cr$/cult. alq.)[1]

X_7 = Seed and Defensives (Cr$/alq.)

X_8 = Machinery Expenses (Cr$/cult. alq.)

X_9 = Labor and Machinery Expenses ($X_6 + X_8$)

X10 = Total Operating Expenses ($X_6 + X_7 + X_8$)

X_{11} = Management Index II (Cr$/alq.)

X_{12} = Ratio of Individual crop land to Cultivated land.

X_{13} = Crop Land (alq.)

X_{14} = All Fertilizer Squared (X_5^2)

X_{15} = Interaction of Lime and All Fertilizer ($X_1 X_5$)

X_{16} = Interaction of Lime and All Fertilizer Squared ($(X_1 X_5)^2$

X_{17} = Interaction of Lime and Nitrogen ($X_1 X_2$)

X_{18} = Interaction of Lime and Phosphate ($X_1 X_3$)

X_{19} = Interaction of Lime and Potash ($X_1 X_4$)

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[1]One U. S. dollar equals approximately Cr$ 4.25.

X_{20} - Nitrogen Squared (X_2^2)

X_{21} - Phosphate Squared (X_3^2)

X_{22} - Potash Squared (X_4^2)

X_{23} - Interaction of Nitrogen and Phosphate (X_2X_3)

X_{24} - Interaction of Nitrogen and Potash (X_2X_4)

X_{25} - Interaction of Phosphate and Potash (X_3X_4)

Fifteen of the variables are not new information, but are transformation of other variables.[1] All independent variables measure the direct application of inputs in the production of a crop except for the labor and machinery use variables.

The labor variable reflects the total labor available for crop production on the sample farms, thus the cost of labor (number of man days times Cr$ 7.00) is equal for all crops and corn because these two groups contain the same farms.[2] This procedure

[1] Transformed variables are X_5, X_9, X_{10} and X_{14} through X_{25}.

[2] The quantity of labor was calculated in the following manner: family labor (If male then 0.5 times the number of days worked by persons from 10 to 14 years of age plus 0.8 times the number of days worked by persons from 15 to 17 years plus 1.0 times the days worked by persons from 18 to 59 years plus 0.8 times the number of days worked by persons of 60 years or more plus if female, then 0.5 times the number of days worked by persons from 10 to 14 years plus 0.8 times the number of days worked by persons from 15 to 59 years plus 0.5 times the number of days worked by persons of 60 years or more) plus the number of days worked by permanent general or crop labor plus the number of days worked by temporary crop labor.

overestimates the labor available for crop agriculture, but a separation of labor into that used on indivdual crops as opposed to cattle and other enterprises was not possible given the level of available information.

Machinery expenses are computed by summing all operating costs, machine hire and 10 percent of the value of the machinery inventory (assumes a 10 percent depreciation on the current value of inventory). This summation is divided by the total cultivated area of the farm, and is thus not a true indicator of machinery use on any specific crop. Management is also equal for any crop on the same farm (Appendix D).

The independent variables entering the aggregate analyses are calculated by summing the use of the input across all crops and dividing by the summation of crop area. The exceptions to this procedure are labor and machinery expenses which were already calculated on the basis of total cultivated area per farm.[1]

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[1] The weights used in calculating the aggregate yield index are based on 1969/70 prices of corn (Cr$ 10.00/60kg.), cotton (Cr$ 10.70/15 kg.), rice (Cr$ 21.50/60 kg.) and soybeans (Cr$ 28.70/60 kg.).

The dependent variables are

Y_1 - Cotton Yield (15 kg. units/alq.)

Y_2 - Rice Yield (60 kg. units/ alq.)

Y_3 - Corn Yield (60 kg. units/alq.)

Y_4 - Soybean Yield (60 kg. units/alq.)

Y_5 - Aggregate Yield Index (Based on 1.00 (Corn Yield) + 1.07 (Cotton Yield) + 2.15 (Rice Yield) + 2.87 (Soybean Yield))

The use of variable inputs varies substantially among crops (Table 17).[1] The average use of lime is about 80 percent of the minimum recommended level of 4.5 to 12.5 tons per alqueire and one lime application will affect soil acidicity for four to six years. If lime application in 1969/70 was normal, it would be equal to an application level of about sixteen tons per alqueire once every four years. The high application level of lime may be due to recent adoption of the practice.

The average ratio of fertilizer nutrients applied is three parts nitrogen (N) to ten parts phosphate (P_2O_5) to five parts potash (K_2O). The ratio does vary slightly among crops, but is initially assumed to reflect the nutrient requirements of crops in the region.

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[1] A more detailed distribution of these variables is given in Appendix F, Tables to 44

TABLE 17.--Mean Values of Crop Yields and Inputs for all sample farms, Ribeirao Preto, 1970

Variables	All Crops	Cotton	Rice	Corn	Soybeans
Y_i - Yield	123.75 (corn equilivant)	198.35 (15 kg/alq.)	68.76 (60 kg/alq)	106.50 (60kg/alq)	64.22 (60 kg/alq)
X - Lime (tons/alq)	3.98	3.96	2.08	5.12	3.11
X_2 - Nitrogen (kg/alq)	30.14	43.96	16.84	34.10	20.65
X_3 - Phosphate (kg/alq)	111.86	183.51	74.47	80.49	111.67
X_4 - Potash (kg/alq.)	58.41	114.47	31.79	51.48	80.00
X_5 - Total Fert. (kg/alq)	197.40	341.95	123.11	166.07	212.32
X_6 - Labor (Cr$/alq.)	231.89	175.91	507.21	231.89	143.53
X_7 - Seed & Defensives (Cr$/alq.)	90.90	267.32	55.50	32.63	138.88
X_8 - Machinery (Cr$/alq)	278.98	284.33	282.98	278.98	314.32
X_9 - Labor & Mach. (Cr$/alq.)	510.87	460.24	790.19	510.87	457.85
X_{10} - All Operating Exp. (Cr$/alq.)	601.77	727.56	845.69	543.49	596.72
X_{11} - Management Index II	1774.40	1811.23	1765.42	1774.40	1873.30
X_{12} = Crop Land/ Cultivated Land	0.79	0.365	0.20	0.42	0.333
X13 - Crop Land (alq.)	46.62	25.55	9.00	18.37	31.84
Farm Size in Cultivated Area (alq.)	55.84	81.26	57.11	55.84	111.59
No. of Observations	151	82	110	151	40

Labor availability was very high on the farms producing rice. These farms are relatively small in size and also the variable reflects the presence of a high proportion of farms from the "other" area (30%) which had a higher percent of the cultivated land devoted to the production of perennial crops (36%) than Guaira or Jardinopolis-Sales. The machinery input was more evenly distributed across crops than labor.

The cost of seed and defensives (insecticides, herbicides, etc.) was much higher on cotton and soybeans than on corn or rice. Insecticides and herbicides made up 85 percent of this variable for cotton production, however the cost of seed was 60 percent of this variable in soybean production.

Management, farm size and machinery expense vary in the same manner across crops with soybeans and cotton being produced on the larger farms. Differences are much greater with regard to size than the other two variables.

Forty-two percent of the cultivated land on the 151 sample farms is used in the production of corn. As the total of these four crops comprise 79 percent of the cultivated area of the sample farms, an average farm produces only one of the other three crops.

The prices used in calculating the value of the marginal product (VMP) are based on an average price received by farmers in the Ribeirao Preto region during the latter half of the 1969/70

agricultural year.[1] They are:

Cotton = Cr$ 10.70/15 kg.

Rice = Cr$ 21.15/60 kg.

Corn = Cr$ 10.00/60 kg.

Soybeans = Cr$ 27.80/60 kg.

All Crops = Cr$ 10.00/unit[2]

The value of the marginal products of variables measured in cruzeiros are intrepreted as the change in value of production due to a Cr$ 1.00 change in the input. The variables measured in physical units (fertilizers and lime) must be evaluated relative to the price per unit of the input. The relevant input prices are:[3]

Nitrogen = Cr$ 1.08/kg.

Phosphate = Cr$ 0.96/kg.

Potash = Cr$ 0.43/kg.

Aggregate Fertilizer = Cr$ 0.83/kg.[4]

Lime = Cr$ 30.00/ton

[1]All yields were transformed to corn equilivants.

[2]All VMP's derived from Cobb-Douglas functions are calculated at the geometric means and those derived from quadratic functions at the arithmetic means.

[3]The fertilizer prices are based on the 1969/70 average price of Cr$ 226.90/ton of ammonium sulfate (21%N), Cr$ 192.95/ton of super phosphate (20% P_2O_5) and Cr$ 257.10/ton of Potassium Clorate (60% K_2O)

[4]Based on an average NPK ratio of 3-10-5.

Functions and Samples

This section outlines the general analysis procedure and presents the models estimated. The analysis began by using disaggregated nonfertilizer variables and an aggregate fertilizer variable. This procedure has been used previously and provides a common base with another study of input productivity in Brazil.[1] Nonfertilizer variables are then aggregated as fertilizer is divided into its separate components In addition, several equations using various interaction variables are fitted to the data. The equations fitted to the regional all crop data are:[2]

I $Y = f(X_1, X_5, X_7, X_9, X_{11}, X_{13})$

II $Y = f(X_1, X_2, X_3, X_4, X_7, X_9, X_{11}, X_{13})$

III $Y = f(X_1, X_5, X_6, X_7, X_8, X_{11}, X_{12}, X_{13})$

IV $Y = f(X_1, X_5, X_{10}, X_{11}, X_{12}, X_{13})$

V $Y = f(X_1, X_5, X_7, X_9, X_{13})$

VI $Y = f(X_1, X_5, X_7, X_9, X_{11})$

VII $Y = f(X_1, X_2, X_3, X_4, X_{10}, X_{11}, X_{12}, X_{13})$

VIII $Y = f(X1, X2, X3, X4, X7, X9, X13)$

IX $Y = f(X_1, X_2, X_3, X_4, X_7, X_9, X_{11})$

X $Y = f(X_2, X_3, X_4, X_7, X_9, X_{11}, X_{13})$

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[1] Akram, op. cit., pp. 41-63.

[2] All functions are in the Cobb-Douglas form except where indicated.

XI $Y = f(X_1, X_5, X_7, X_9, X_{11}, X_{13}, X_{14},)$[a]

XII $Y = f(X_7, X_9, X_{11}, X_{13}, X_{15}, X_{16})$[a]

XIII $Y = f(X_1, X_2, X_3, X_4, X_{10}, X_{20}, X_{21}, X_{22}, X_{23}, X_{24}, X_{25})$[a]

XIV $Y = f(X_7, X_9, X_{11}, X_{13}, X_{17}, X_{18}, X_{19})$

The observations were sorted by location and the following all crop equations were estimated for Guaira, Jardinopolis-Sales de Oliveira and other areas:

I $Y = f(X_1, X_5, X_7, X_9, X_{11}, X_{13})$

II $Y = f(X_1, X_2, X_3, X_4, X_7, X_9, X_{11}, X_{13})$

III $Y = f(X_1, X_5, X_6, X_7, X_8, X_{11}, X_{12}, X_{13})$

IV $Y = f(X_1, X_5, X_7, X_9, X_{11}, X_{13})$

V $Y = f(X_1, X_2, X_3, X_4, X_7, X_9, X_{11}, X_{13})$

VI $Y = f(X_2, X_3, X_4, X_7, X_9, X_{11}, X13)$

The all crop production data was also disaggregated by crop and individual functions were fitted to regional crop data. The following functions were fitted:

I $Y = f(X_1, X_5, X_7, X_9, X_{11}, X_{13})$

II $Y = f(X_1, X_2, X_3, X_4, X_7, X_9, X_{11}, X_{13})$

III $Y = f(X_1, X_5, X_6, X_7, X_8, X_{11}, X_{12}, X_{13})$

IV $Y = f(X_1, X_2, X_3, X_4, X_{10}, X_{13})$

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[a]Quadratic form of the function.

V $Y = f(X_2, X_3, X_4, X_{10}, X_{20}, X_{21}, X_{22}, X_{23}, X_{24}, X_{25})$[a]

The individual crop data were sorted by location and various levels of fertilizer application. The following functions were fitted to the subgroups:

I $Y = f(X_1, X_5, X_7, X_9, X_{11}, X_{13})$

II $Y = f(X_1, X_2, X_3, X_4, X_7, X_9, X_{11}, X_{13})$

III $Y = f(X_1, X_2, X_3, X_4, X_7, X_9, X_{20}, X_{21}, X_{22}, X_{24}, X_{25})$[a]

As stated previously, functions were fitted to all observations in the region and to data from each of the locations within the region. The individual crop data were also sorted by levels of fertilizer use. The first system (Sample A) was based on the assumption that high level use of fertilizer would yield different regression coefficients than for the low level fertilization group.

The second division (Sample B) based on fertilizer use levels was an attempt to minimize the variation in fertilizer use within each group. Thus, observations exhibiting extremely high or low levels of fertilization or an abnormal distribution of nutrients were eliminated. The remaining observations were grouped on the basis of minimizing the variation within groups, yet maintaining sufficient sample size.[1]

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[a]Quadratic form of the function.

[1]The means of all variables in each subgroup are presented in Appendix F.

CHAPTER V

PRODUCTIVITY ANALYSIS

The purpose of this chapter is to report the results of the statistical estimation of the production coefficients and values of the marginal products derived from them for the sample farms. Complete models are presented for only the regional all crop and individual crop samples. Model's I and II, which are consistantly the better fitting equations, are used to represent the relationship between crop yield and inputs and are also the base for the value of the marginal products (VMP) presented in the latter part of the chapter.[/]

Regional Production Analysis

All Crops

As can be seen in Table 18, lime use yields a positive VMP, however it is substantially lower than the price of lime at Cr$30.00 per unit. The value of lime applied to acidic soil is difficult to evaluate in terms of its VMP as its effect may last from four to six years and no information was available on the acidity of the soils by specific area.

The regression coefficient of all fertilizer is not significant at either the 0.50 or the 0.10 level, thus the effect on crop yield by all fertilizer is nil. Even if the regression coefficient were significant, its absolute value also approaches zero. The reason for this can be under- by viewing the coefficients of the individual nutrients. Nitrogen has a negative effect while phosphate and potash have a positive effect on yield thereby offsetting the nitrogen effect. Only potash yields a

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[/] All other functions are given in Appendix G.

Table 18 Regional All Crop Production Functions

Variables	Model I		Model II	
	Regression Coefficients[a]	Value of Marginal Product[b]	Regression Coefficients[a]	Value of Marginal Product[b]
		(Cr$)		(Cr$)
Constant	2.130		2.255	
X_1 = Lime	0.014* (0.016)	4.36	0.018* (0.016)	5.60
X_2 = Nitrogen			-0.067** (0.025)	-5.36
X_3 = Phosphate			0.014* (0.022)	0.33
X_4 = Potash			0.036* (0.023)	1.90
X_5 = All Fertilizer	0.003 (0.021)	0.03		
X_7 = Seed & Defensives	0.203** (0.029)	4.66	0.198** (0.029)	4.55
X_9 = Labor & Machinery	0.098** (0.036)	0.32	0.109** (0.036)	0.35
X_{11} = Management Index II	0.145** (0.084)	0.11	0.126** (0.082)	0.10
X_{13} = Crop Land	-0.031* (0.028)	-1.88	-0.039* (0.028)	-2.36
Standard Error of Estimate	0.394		0.353	
Simple R^2	0.360		0.426	
F - Ratio	15.621**		13.181**	

* Significant at 0.50 level

** Significant at 0.10 level

[a] Numbers in parentheses are the standard errors.

[b] VMP's are calculated at the geometric means of the variables.

VMP which is greater than its cost. Potash returns a profit of Cr$1.47 per kilogram if associated costs of fertilization are ignored.

Seed and defensives (herbicides, insecticides, etc.) yield a high return per cruzeiro of expense. Labor and machinery expenses, however, do not return the full amount of their cost. As mentioned in the previous chapter, a precise measurement of these two inputs was not obtainable and X_9 is an overestimate of the quantity of labor and machinery used on the four crops included in the all crop yield variable. Three-fourths of the cultivated land area is included in these four crops and the VMP of X_9 indicates that only 30 percent of their cost is returned, therefore the remaining Cr$0.70 per Cr$1.00 of cost would have to be returned by twenty-five of the cultivated crop area and the value of family labor in livestock enterprises if the present usage were to be at an economic optimum.

A previous study of crop agriculture in Brazil found positive returns to scale, however this analysis indicates that the returns are to management, not scale.[/] A direct comparison cannot be made as the coefficient of crop land remains negative as management is removed from the equation.[/]

Corn

The response of corn yields to fertilizer is very similar to that of the all crop composite yield (Table 19). The regression coefficient of all fertilizer is insignificant at either of the two indicated levels,

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/ Akram, op. cit., pp. 47-67.

/ See functions V, VII, VIII, and IX, Appendix G, Tables 45.

Table 19 Corn Crop Production Functions for the Ribeirao Preto Region

Variables	Model I Regression Coefficients[a]	Model I Value of Marginal Product[b] (Cr$)	Model II Regression Coefficients[a]	Model II Value of Marginal Product[b] (Cr$)
Constant	2.262		2.331	
X_1 = Lime	-0.029* (0.019)	-10.334	-0.024* (0.020)	-8.55
X_2 = Nitrogen			-0.040* (0.025)	-2.80
X_3 = Phosphate			0.014 (0.024)	0.46
X_4 = Potash			0.020* (0.027)	1.22
X_5 = All Fertilizer	0.011 (0.024)	0.11		
X_7 = Seed and Defensives	0.154** (0.066)	5.20	0.149** (0.066)	5.03
X_9 = Labor & Machinery	0.130** (0.058)	0.33	0.129** (0.058)	0.33
X_{11} = Management Index II	0.119* (0.092)	0.07	0.020* (0.091)	0.07
X_{13} = Crop Land	0.027* (0.032)	2.82	0.027* (0.032)	2.82
Standard Error of Estimate	0.405		0.403	
Simple R^2	0.127		0.150	
F - Ratio	3.478**		3.128**	

* Significant at 0.50 level

** Significant at 0.10 level

[a] Numbers in parentheses are the standard errors.

[b] Calculated at the geometric means.

however both nitrogen and potash are significant at a 0.50 level. Nitrogen use again exhibits a negative relationship to corn yield.

The regression coefficients and VMP's of all other inputs, except that of lime and land, are similar to those estimated for the all crop function. The regression coefficient for lime is negative and a positive relationship between yield and crop land is shown by the equations.

Rice

Only potash has a positive VMP in the production of rice (Tabla 20). It is, however, not significant at either the 0.50 or 0.10 levels. Nitrogen, phosphate, and all fertilizer have negative VMP's.

The regression coefficient of lime is positive and significant at the 0.50 level. It's VMP is also greater than the cost of lime in this case. Seed and defensives, labor and machinery, and management are significantly (at a level of 0.10) and positively related to rice yield. Crop land is inversely related to rice yield as shown by a negative regression coefficient which is significant at a 0.50 level.

Cotton

The regression coefficient of nitrogen in cotton production is consistent with the three previously presented functions (Tabla 21). It is significant at a 0.50 level and yields a negative VMP of -Cr$3.88. Phosphate and potash have positive VMP's which are greater than their price, however only the regression coefficient of phosphate is significant at a 0.50 level. The coefficient for all fertilizer is not significant at the 0.50 level.

Table 20 Rice Crop Production Functions for the Ribeirao Preto Region

Variables	Model I		Model II	
	Regression Coefficients[a]	Value of Marginal Product[b]	Regression Coefficients[a]	Value of Marginal Product[b]
		(Cr$)		(Cr$)
Constant	0.744		0.665	
X_1 = Lime	0.054* (0.032)	32.55	0.055* (0.032)	33.15
X_2 = Nitrogen			-0.064* (0.062)	-12.42
X_3 = Phosphate			-0.077** (0.032)	-3.84
X_4 = Potash			0.038 (0.059)	4.85
X_5 = All Fertilizer	-0.090** (0.034)	-1.94		
X_7 = Seed & Defensives	0.086** (0.048)	3.70	0.087** (0.049)	3.74
X_9 = Labor & Machinery	0.184** (0.102)	0.39	0.177** (0.104)	0.38
X_{11} = Management Index II	0.334** (0.179)	0.24	0.344** (0.181)	0.25
X_{13} = Crop Land	-0.079* (0.061)	-22.92	-0.088* (0.062)	-25.54
Standard Error of Estimate	0.571		0.572	
Simple R^2	0.200		0.209	
F - Ratio	4.224**		3.331**	

* Significant at 0.50 level

** Significant at 0.10 level

[a] Numbers in parentheses are the standard errors.

[b] Calculated at the geometric means.

Table 21 Cotton Crop Production Functions for the Ribeirao Preto Region

Variables	Model I		Model II	
	Regression Coefficients[a]	Value of Marginal Product[b] (Cr$)	Regression Coefficients[a]	Value of Marginal Product[b] (Cr$)
Constant	4.299		4.322	
X_1 = Lime	0.025* (0.020)	12.56	0.029* (0.020)	14.57
X_2 = Nitrogen			-0.052* (0.042)	-3.88
X_3 = Phosphate			0.048* (0.038)	0.93
X_4 = Potash			0.023 (0.037)	0.71
X_5 = All Fertilizer	0.015 (0.043)	0.14		
X_7 = Seed & Defensives	0.075* (0.066)	0.70	0.068* (0.066)	0.64
X_9 = Labor & Machinery	-0.024 (0.104)	-0.11	-0.018 (0.103)	-0.08
X_{11} = Management Index II	0.031 (0.125)	0.04	0.028 (0.123)	0.03
X_{13} = Crop Land	0.067* (0.045)	10.44	0.052* (0.045)	8.10
Standard Error of Estimate	0.388		0.380	
Simple R^2	0.133		0.187	
F - Ratio	1.910**		2.104**	

* Significant at 0.50 level

** Significant at 0.10 level

[a] Numbers in parentheses are the standard errors

[b] Calculated at the geometric means

Two aspects of the equation fitted to cotton production data are different from previous equations. First, the VMP of seed and defensives is less than 1.00 indicating an unprofitable level of use. Second, returns to scale are high relative to returns found in any of the other functions.

Soybeans

Contrary to accepted thought, nitrogen yields a high, positive VMP (significant at 0.50 level) in the production of soybeans (Tabl. 22). The level of use, however, is very low (21.65 kg./alq.) and the VMP of nitrogen may decrease rapidly at higher levels of application. Phosphate, potash, and all fertilizer are not significantly related to yield at a 0.50 level.

Cash expenses of seed, defensives, labor and machinery yield positive and significant regression coefficients (0.50 level). The VMP's of these variables are greater than their cost in all cases. Management is positively and significantly (0.10 level) related to yield. The regression coefficient of crop land is negative and only significant at the 0.50 level in one of the two equations.

Variations in the effect of inputs exist between crops, however the following general statements can be made. The application of lime to reduce soil acidity yields a significant and positive VMP, however not equal to its cost per unit in one production period. As the effect of lime remains from four to six years, an accurate evaluation of optimum lime usage requires time series information which was not available in this study.

Table 22 Soybean Crop Production Functions for the Ribeirao Preto Region

Variables	Model I		Model II	
	Regression Coefficients[a]	Value of Marginal Product[b] (Cr$)	Regression Coefficients[a]	Value of Marginal Product[b] (Cr$)
Constant	-0.811		-0.972	
X_1 = Lime	0.036 (0.048)	9.30	0.041* (0.049)	10.60
X_2 = Nitrogen			0.004 (0.065)	1.88
X_3 = Phosphate			-0.019 (0.057)	-0.70
X_4 = Potash			0.038 (0.062)	2.94
X_5 = All Fertilizer	0.011 (0.054)	0.19		
X_7 = Seed & Defensives	0.135* (0.118)	2.05	0.149* (0.127)	2.26
X_9 = Labor & Machinery	0.279** (0.172)	1.00	0.284** (0.180)	1.02
X_{11} = Management Index II	0.356** (0.259)	0.29	0.372** (0.267)	0.31
X_{13} = Crop Land	-0.056 (0.096)	-4.69	-0.069* (0.100)	-5.77
Standard Error of Estimate	0.517		0.528	
Simple R^2	0.167		0.183	
F - Ratio	1.105*		0.867*	

* Significant at 0.5 level

** Significant at 0.10 level

[a] Numbers in parentheses are the standard errors

[b] Calculated at the geometric mean

Cash expenditures for seed and defensives yield high returns, two to five times their cost.[/] It appears that the greatest increase in production and profits in the region can be obtained through increasing the average expenditure per alqueire on seeds and defensives.

There appears to be a surplus of labor and machinery in the region as the average return to these inputs is considerably less than their cost at the margin. This variable overestimates the actual cost in crop production, therefore no firm conclusions can be made on the basis of this analysis.

Management, as measured by Index II, and size, as measured by crop land, are positively correlated, but their individual effects on yield are quite different. The management index is positively related to yield and significant in all but one case. Returns to scale are negative for two of the four individual crops and in the aggregate crop function.

Economics of Fertilization

The value of the marginal products presented in this section are derived from the regression coefficients of Model's I and II. The economics of fertilization is discussed in terms of location by crop in the first portion of this section and level of fertilizer use by crop in the last part.

Location and Crop

The sample was divided into three subgroups to investigate the general lack of significant response to fertilizer in the regional models. The underlying hypothesis was that differences in soil types between the areas

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[/] Cotton production is an exception returning only 60-70 percent of their cost.

may have hidden the real effects of fertilization. This hypothesis is found to be generally false although some differences do exist. Also, fewer of the fertilizer variables are significant in the location sub-samples than in the regional sample.

The pattern of the VMP's derived from Guaria farms corresponds with the regional VMP's very closely (Table 23). Only cotton exhibits a positive and significant response (0.10 level) to any of the nutrients, returning Cr$2.51 per applied kilogram of potash.

The production of rice and cotton in Jardinopolis-Sales de Oliveira is distinctive due to positive VMP's with regard to nitrogen and negative VMP's with regard to potash. In both cases, the mean values of the fertilizer nutrients applied are almost indentical to the regional values, thus negating the hypothesis that these differences are due to changes in the level of use.

The fertilizer VMP's derived from the regression analysis of crops from other areas in the region corresponds to the regional results. As in the regional analysis, there are major differences in the VMP's between crops. These differences between crops are much greater than differences in VMP's between locations within the same crop. There is no new information in this comparison, however to suggest a reversal of the conclusion of the regional production analysis that only potash application is returning a profit to the farmer.

Level of Use and Crop

A second subdivision of the sample was made in an attempt to determine if the level of fertilizer use had an influence on the VMP's. This was done specifically to recheck the insignificant and negative regression

Table 23 Value of the Marginal Product of Fertilizer by Nutrient, and Location[a]

Location and Crop	Value of Marginal Product in Cruzeiros/Kg.[b]			
	Nitrogen	Phosphate	Potash	All Fertilizer
Ribeirao Preto Region				
All Crops	-5.36**	0.33*	1.90*	0.03*
Corn	-2.80*	0.46	1.22*	0.11
Rice	-12.42*	-3.84**	4.85	-1.94
Cotton	-3.88*	0.93*	0.71	0.14
Soybeans	1.88	-0.70	2.94	0.19
Guaira				
All Crops	-3.04*	-0.02	1.79	0.04
Corn	-2.87	1.00	0.96	0.34*
Rice	-14.42*	-5.54**	5.33	-2.64**
Cotton	-8.65**	-0.02	2.51**	-0.15
Soybeans	8.09	-0.98	2.28	0.11
Jard.-Sales				
All Crops	-4.38	0.41	1.45	-0.01
Corn	-2.68	0.00	1.70	0.27
Rice	10.97	-5.38*	-3.50	-2.04*
Cotton	3.89*	1.74*	-2.75*	0.46*
Other Areas				
All Crops	-2.76*	0.49	0.41	-0.01
Corn	-1.54	0.47	1.20	0.44
Rice	-51.31*	-4.54*	3.90*	-1.18

* Significant at 0.50 level

** Significant at 0.10 level

[a] The complete equations are presented in Appendix G.

[b] Calculated at the geometric means.

coefficients found in earlier analysis.

The high use level of Sample A includes observations with exceptional high application levels of one of the three nutrients.—/ All other observations are included in the low-use sample (Table 24). The response of yield to individual nutrients in the high-use group is consistent with the regional results, however the VMP of all fertilizer for corn, rice and cotton is positive, significant at the 0.50 level and greater the composite price of all fertilizer (Cr$1.50 to 1.63 as compared to Cr$0.83). This appears to be due primarily to higher levels of phosphate and potash applications and their higher VMP's. Fertilizer application by low level user is generally not profitable.

The criterion for selecting the various subsamples of Sample B was to minimize the varience within each subgroup.—/ This entailed the removal of all extreme observations. The two sets of observations of corn and soybean observations (Sample B, Total Group) exhibit similar VMP's. There is a negative response to nitrogen, and a positive response to phosphate, potash and all fertilizer. The VMP is greater than the input price for all of the positive VMP's, however the coefficients are significant only for corn production. Two of the three equations fitted to observations in the high group also yield positive VMP's, however only the VMP of all fertilizer in corn production is positive and greater than its cost. In the low group, none of the regression coefficients are

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—/ See Appendix F for the specific levels of fertilization.

—/ The data used in this analysis are given in Appendix F .

Table 24 Value of the Marginal Product of Fertilizer by Nutrients, Level of Use and Crop[a]

Level of Use and Crop[b]	Value of Marginal Product in Cruzeiros/Kg.[c]			
	Nitrogen	Phosphate	Potash	All Fertilizer
Ribeirao Preto Region				
Corn	-2.80*	0.46	1.22*	0.11
Rice	-12.42*	-3.84**	4.85	-1.94
Cotton	-3.88*	0.93*	0.71	0.14
Soybeans	1.88	-0.70	2.94	0.19
Sample A				
High Group				
Corn	-2.04*	0.18	3.16*	1.15**
Rice	-9.12	-1.55*	3.38	1.40*
Cotton	-0.75	2.37**	1.13	1.63*
Soybeans	-15.17	0.93	0.52	0.02
Low Group				
Corn	-4.46*	1.38	0.71	-0.09
Rice	-22.13	-11.84**	18.79*	-3.76*
Cotton	-6.07	-0.62	-3.35	0.44
Soybeans	-72.42*	-13.05*	23.38*	-2.34*
Sample B				
Total Group				
Corn	-0.85	1.06*	3.05**	1.41**
Soybeans	-0.06	5.84	1.03	2.70
High Group				
Corn	-2.68*	0.60	2.46*	0.84*
Rice	-4.71	0.18	0.41	-0.12
Cotton	7.51*	0.25	-4.62	0.74
Low Group				
Corn	2.39	0.40	0.21	0.24
Rice	-22.94	-32.71	50.57	-1.31
Cotton	-6.07	0.62	-3.35	0.44

* Significant at 0.50 level
** Significant at 0.10 level

[a] The complete equations are presented in Appendix G.

[b] Calculated at the geometric means.

[c] There were insufficient observations in some subgroups for regression analysis.

significant at either the 0.50 or 0.10 level.

Quadratic functions were fitted to the data to investigate the effect of a different type of function which yields direct estimates of interaction between nutrients. The VMP's derived from the quadratic functions usually have the same sign as those derived from the Cobb-Douglas function, however their absolute value is normally greater than those derived from the Cobb-Douglas functions (Table 39). This may be partially due to the interaction effects and partially due to multicollinearity introduced by the interaction and squared terms. The quadratic functions also decreases the degrees of freedom by requiring nine independent variables to measure the fertilizer input. Another problem is that the VMP's derived from quadratic functions are calculated using four regression coefficients, all of which were seldom significant at either the 0.50 or 0.10 levels.

The VMP of nitrogen is negative in fourteen of the twenty-one cases (negative in 9 of 10 cases which are significant), thus supporting results of previous analysis. Nitrogen use in cotton production may be profitable, however, when applied with high levels of phosphate and potash as indicated by positive VMP's in the regional, Sample A: High-use and Sample B: High-use.

The VMP's of phosphate are also negative in about one-half of the cases (negative in 5 of 7 cases which are significant). The application of phosphate may be profitable on corn, cotton and soybeans

TABLE 25.--Value of marginal product of fertilizer by nutrient, level of use and crop as derived from quadratic functions[a]

Level of Use and Crop	Value of Marginal Product in Cruzeiros/kg.[b]			
	Nitrogen	Phosphate	Potash	All Fertilizer
Ribeirao Preto Region				
All Crop	-8.99*	1.98*	3.83*	0.46*
Corn	-2.86	-0.27[c]	3.04*	
Rice	-2.85*	-0.17*	-0.23*[c]	
Cotton	7.13[c]	1.23	0.60	
Soybeans	-40.48	-6.28	1.92	
Sample A				
High-Use Group				
Corn	-0.86	1.38	3.15*	2.60*
Rice	-12.11*	-7.02*	8.18*	-2.30[c]
Cotton	5.17*[c]	-3.06*[c]	11.77*	4.75*
Soybeans	7.45[c]	2.69	-1.13[c]	0.35
Low-Use Group				
Corn	-4.04*	-0.64[c]	3.63	0.43[c]
Rice	9.68[c]	-13.39	-14.93[c]	-5.79*
Cotton	-113.86*	4.23[c]	5.66[c]	-0.05[c]
Soybeans	-93.07*	-44.31	11.37	-7.56*
Sample B				
Total Group				
Corn	-2.55	5.48	5.23	
Soybeans	15.79[c]	27.94	-5.81[c]	
High-Use Group				
Corn	-8.30*	5.95	20.83	
Rice	-64.13	-1.58[c]	8.52	
Cotton	14.98	8.66*	17.13[c]	
Low-Use Group				
Corn	4.19	-0.78*[c]	12.64	
Rice	-199.23*	-551.63*	-392.52[c]	
Cotton	-35.63*	5.61	32.83[c]	

[a]The complete equations are in Appendix 6.

[b]Calculated at arithmetic means of the variables.

[c]The VMP's have the opposite sign of those derived from Cobb-Douglas functions.

*Three of the four regression coefficients entering the calculation of VMP are significant at the 0.50 level.

under good management techniques as the VMP's for the high-use samples are normally positive.

The use of potash is profitable at present use levels, as indicated by the VMP's, in the production of corn and cotton. Soybean yields are increased by potash use only under conditions of low fertilizer usage whereas rice yields respond to potash only when high quantities of fertilizer are applied.

The present levels of all fertilizer yield a net positive return only under high-use conditions in production of corn and cotton. The total effect of fertilizer is significant and negative in rice and soybean production under low use levels.

The division of the sample into high and low groups reveals that a positive net return to fertilizer is obtained when relatively high fertilizer levels are applied and a fixed proportion of phosphate and potash are applied. Nitrogen, however, yields a negative VMP in most cases.[1] VMP's derived from quadratic functions have the same sign as those derived from Cobb-Douglas functions in most cases, however are normally larger in absolute value.

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[1]The exceptions are Sample B, high group for cotton and Sample B, low group for corn.

Summary

Potash is the only fertilizer nutrient to consistently yield positive VMP's which are greater than its cost. Phosphate, while regression coefficient normally is positive, seldom yields VMP's which are significant and greater than or equal to its price. Nitrogen normally exhibits a significant regression coefficient, but it is negative in nearly all instances.

The implications of these results are quite serious for Brazilian agriculture. Much effort has been made through price and credit concessions, advertizing and educational programs to promote fertilizer use in Brazil by the public and private sector. These results when considered with the results of other analyses reviewed in Chapter II cast serious doubt upon the assumption underlying the public and private programs, i.e. fertilizer application yields a positive net return to the farmer and to society. A few of the possible reasons for lack of response to fertilizer, a possible rationale why farmers are presently using an unprofitable quantity of fertilizer, and the implications of these results are discussed in the following chapter.

CHAPTER VI

POSSIBLE CAUSES OF THE FERTILIZER PROBLEM

The analysis of fertilizer usage in the previous chapter raises two important questions: (1) what are the factors inhibiting a profitable response to fertilizer and (2) why are farmers presently using unprofitable levels and/or combinations of fertilizer nutrients. The second question is discussed in the first part of this chapter and various possible answers to the first question are explored in the last half of this chapter.

Actual Versus Optimum Fertilizer Usage

As mentioned previously in Chapter III, the average use of fertilizer in the Ribeirao Preto area is below the recommendations of the fertilizer industry and extension service, however the actual use also varies greatly from the optimum indicated by the VMP's derived from this analysis (Table 26).

The actual fertilizer use by farmers in the area is nearer the application levels indicated by the VMP's derived from this analysis than are the levels recommended by the extension service and the industry representatives. This supports the Schultzian hypothesis that farmers are economically rational men. The relationship between fertilizer recommendations and the VMP's can also explain

TABLE 20.--Summary of fertilizer use and it's value of marginal product by crop[a]

Fertilizer and Crop	Average Fertilizer Use Quantity (kg./alq)	% of Minimum Recommendation	Value of Marginal Product (Cr$)
All Crops			
(1) Nitrogen	30.14	36	-5.36**
(2) Phosphate	111.86	89	0.33*
(3) Potash	58.41	132	1.90*
(4) All Fertilizer	199.41	79	0.03*
Cotton			
(1) Nitrogen	43.96	56	-3.88*
(2) Phosphate	183.51	127	0.93*
(3) Potash	114.47	100	0.71
(4) All Fertilizer	341.95	102	0.14
Rice			
(1) Nitrogen	16.84	56	12.42*
(2) Phosphate	74.47	52	-3.84**
(3) Potash	31.79	106	4.85
(4) All Fertilizer	123.11	60	-1.94
Corn			
(1) Nitrogen	34.10	24	-2.80*
(2) Phosphate	80.47	74	0.46
(3) Potash	51.48	234	1.22*
(4) All Fertilizer	166.07	61	0.11
Soybeans			
(1) Nitrogen	20.65	94	1.88
(2) Phosphate	111.67	103	0.70
(3) Potash	80.00	364	2.94
(4) All Fertilizer	212.32	140	0.19

[a]VMP's derived from regional Models I and II.

[b]Fertilizer prices are: (1) Nitrogen, Cr$ 1.08/kg.; (2) Phosphate, Cr$ 0.96/kg; Potash, Cr$ 0.43/kg.; and (4) total fertilizer, Cr$ 0.83/kg.

the farmer's level of fertilizer use under certain conditions. If one assumes the following decision function and no change in price relationships,

$$U = p(R) + 1-p\,(E)$$

where: U = Level of Fertilizer Use

p = Probability that the recommendations are correct

R = Recommended level

1-p = Probability that farmer's experience is correct

E = Optimum use level based on experience

then the present use levels could be determined if p, R and E were known. In the case of cotton, for example, values of p = 0.5, R = 80 and E = 0 determine a fertilizer use level of 40 kg./alq. of nitrogen which is close to the average use in the region. Both p and E, however, are unknown and are both a function of the number of years which the farmer has used fertilizer.

The apparent inaccuracy of the recommendations may be due to their generality. The general fertilizer recommendations for the state are used within the region by extension agents and fertilizer dealers as no regional or subregional recommendations are available. Major differences may also exist between response to fertilizer under experimental conditions and in a farm operation, assuming the recommendations are based on experimental results. Another possible,

although improbable, explanation is that the recommendations are biased upward by the fertilizer industry and extension service in an effort to stimulate fertilizer use. Irregardless of the reason for the apparent erroneous recommendations, there is a great need to evaluate them in view of actual responses to fertilization on the farm level. A greater need exists, however, to determine what factors are inhibiting yield response to nitrogen and phosphate application. Some of these factors are discussed in the next section.

Factors Affecting the Response to Fertilization

There are two sets of factors which may have caused the results found in this study. First, there may be a set of circumstances unique to this sample which inhibited the response to fertilizer and make these results not representing of the general case. Second, there may be factors which are inhibiting crop response to fertilizer which have general applicability for much of Brazil's agriculture.

Factors Specific to This Study

Factors which would make these results not applicable to the general case are: (1) an abnormal climate during the 1969/70 agricultural year in the Ribeirao Preto region; (2) uniqueness of the sample farmers in their usage of fertilizer; (3) inaccuracy of the data; or (4) the method of analysis. As suggested earlier, during the

1969/70 agricultural year, all climatic factors appear normal. Rainfall, which is the critical factor in affecting crop response to fertilizer, was within the normal range of 1100 to 1700 mm..[1] The distribution of rainfall also appears to be within a normal range. Crop yields of the sample farmers were higher than the five year average for the region, this it appears that the conditions were not unsatisfactory for obtaining response to ferilizers.

As previously stated, the original sample was chosen randomly within a size and enterprise stratification. This stratification closely follows the distribution of commercial agriculture in the region.[2] The specific observations included in this analysis were those farms specializing in crop agriculture and if a bias occurs, it should be a upward bias as these farmers are specialists in the production of annual crops.

The third possible factor which could influence these results is inaccurate data. Several precautions such as interviewer training, field checks of the questionnaires, and detailed checks of the data used in this analysis were made to prevent this possibility. Some inaccuracies may remain, however, it is not believed that they are of such a magnitude to inviolate the results.

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[1] See the description on p .

[2] Kelso Wessel and William Nelson, op. cit.

Cobb-Douglas and quadratic functions were fitted to several subsamples based on location and level of fertilizer use. Several combinations of variables were also used to recheck and substantiate the regression coefficients found in the regional analysis. There was some variation in VMP's due to changes in crops, location and use-levels, but the response to nitrogen consistently remained negative and the VMP's of all fertilizer were greater than the price only under conditions of high, balanced application levels. These results do not refute the existence of the serious problemthat the usage of fertilizer is not economical in this region under average conditions.

There is one other set of factors which may be important in the region and throughout Brazil. The first of these factors is inaccurate or false labeling of fertilizer with respect to the available nutrients. This problem was mentioned voluntarily by three of the sixteen fertilizer dealers interviewed in the region. Naturally, it was another dealer's fertilizer which was supposed to be misrepresented. In addition to the accusations of three dealers, one interview with a large company dealership was interupted by a sales agent who reported that one of his customers had independently checked the composition of the fertilizer. The analysis had found large differences between the actual and stated contents of the fertilizer. The problem

may be one of quality control in many of the small mixing plants scattered throughout the state. A state agency has responsibility for checking the accuracy of formulas, however the large number of mixing plants and insufficient personnel make the task nearly impossible.[1]

The type of formulas which are most readily available to the farmer may be a major factor in the usage of nitrogen in the region.[2] Most of the fertilizer sold in the region is of the premixed type and contains a low percentage of nitrogen.

The system of granting credit for fertilizer may also decrease to flexibility of the farmer in choosing plant nutrients. Agronomos (persons with a college degree in general agriculture), trained to follow the recommendations of the extension service, are employed by several of the major agricultural lending institutions in the region to approve or reject loan applications for fertilizer purchases. This system may require the use of nitrogen as a formal requirement or through informal pressures.

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[1] Based on informal conversations with fertilizer dealers and personnel from Escola Superior da Agricultura "Luiz de Queiroz" (ESALQ) and Associacao Nacional para Difusao de Adubos (ANDA).

[2] The most common formulas are of the proportions 3-15-15 and 4-14-8.

The operation of the fertilizer credit system may cause another problem in fertilizer usage. Until July 31, 1970, credit was granted for fertilizer purchases at zero nominal interest rates, less expensive than any other type of agricultural credit. These is a possibility that credit was obtained for fertilizer purchases through this system, yet no purchase was actually made. Also, some large farmers buy fertilizer with subsidized credit and resell it to small farmers according to people in the region. Due to the check made by the interviewer and/or his supervisor between fertilizer use and credit, some fertilizer may have entered as applied to a crop when, in fact, it was resold or never purchased.[1]

General Factors

There are several possible factors which may inhibit or prevent a response of crop yield to fertilizer. Certain of these, soil conditions, crop varieties, application methods, improper balance of nutrients, and "sufficient use" are briefly discussed in the context of their probability of being the inhibiting factor.

On the basis of this study, research cited in Chapter II, and informal conversations with soil scientists, the characteristics of the soil in the region appear to have the highest probability of being

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[1] There were no occurances of reselling fertilizer reported by farmers during the personal interviews.

the key to the lack of response to nitrogen and phosphate. The dominate soil type in the area is terra roxa (red soil) which is normally acidic with high amounts of iron and bauxite. Nitrogen is normally applied in the form of ammonium sulfate (NH_3SO_4) which will produce sulfuric acidic (H_2SO_4) when bought in contact with soil moisture. Thus, the possiblity exists that the application of nitrogen may decrease yields due to increasing soil acidicity more than increasing them due to the effect of nitrogen.

Terra roxa, as are the other soils in the region, is a conglomerate, mineral soil which will allow water and water soluble material to pass through very rapidly. Ammonium sulfate is very soluble and could "leech" out of the top soil given the proper conditions of heavy rainfall soon after application. A second possibility for the lack of response to nitrogen is a possible existence of micro-organisms in the soil which "use up" the nitrogen thereby making it unavailable for plants.

Phosphate has an affinity for iron and bauxite, thus in these soil types a process called phosphate fixation occurs.[1] Phosphate applied to these soils becomes "fixed" and not available for plant growth.

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[1] The reaction between phosphate, iron and bauxite is much higher in acidic soils than neutral or alkline soils.

Seed variety is another factor affecting the response to fertilizers. The popular phase "Green Revolution" is based on the large increases in yields brought about by new crop varieties which are responsive to fertilizer. The revolution has not occurred on a wide scale in Brazil, yet the high VMP's found in this study of seed and defensives imply that these inputs are very important in the Brazilian setting. The effect of crop varieties is probably less important than soil problems as low responses to fertilizer in all crops were obtained under average levels of fertilizer use.

The method of fertilizer application (timing and distance to plant) affects crop response to fertilizer. This is especially true with respect to nitrogen as its application may have different effects when applied at planting time or as sidedressing when plants are six to eight inches high. The relationship between rainfall and fertilizer is also critical as nitrogen application can "burn" crops if rainfall is not sufficient.

Proper balance of the three major nutrients and micronutrients is necessary for significant fertilizer response. No information was available on micronutrients, however, a selected sample (Sample B, all and high groups yielded a positive net return to fertilizer while the total sample did not yield a VMP equal to or greater than fertilizer cost.

conditions, is not uncommon in Brazil. Factors which appear to have the best probability of being the key to unlocking high responses to fertilization are soil conditions, crop varieties, application methods and proper balance and level of nutrient use. Research is needed to gain information on each of these factors and the information should be passed to the farmer as rapidly as possible. The type of regional research needed appears to be similar to that used by a project to increase corn yields in Mexico.[1] Their methodology is summarized in the following paragraph:

> It was found necessary to study all of the major variables influencing the expression of yield as part of an integrated experiment. Consequently experiments were designed to include rates of nitrogen and phosphorus, plant population, timing of nitrogen application, planting dates, plant genotype, weed control and even cultural practices to improve moisture storage. Especially significant is the work to integrate the agronomic studies with varietal selection in multivariate experimentation.

Myren goes on to state "The complex problems of raising yields on small holdings under natural rainfall conditions require the joint efforts of agronomic and social scientists.[2] This type of project is applicable to a region like Ribeirao Preto where the research

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[1]Delbert T. Myren, op. cit., p. 28.

[2]Ibid., p. 37.

"Sufficient use" of fertilizer may be important as the higher levels of use yielded significant coefficients more often than lower application levels. Positive net returns for all fertilizer were consistently obtained at the high use levels. In fact, there was only two instances of a positive and significant regression coefficient with regard to any of the individual nutrients or all fertilizer in the low fertilizer use groups.[1]

Summary

The farmers in the region were applying fertilizer in closer relationship to the economic optimums indicated by this study than were the recommendations of the state extension service and the fertilizer industry. The recommendations were state-wide, thereby ignoring local and regional differences in soil and climate.

Two sets of factors may be preventing yield increases due to fertilization, those unique to the sample or those which may be general for much of Brazil. The factors unique to the study, climate, sample farms, accuracy of data and method of analysis, are not believed to be the cause of the problem. As the review of literature has shown, the lack of response to fertilizer, even under experimental

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[1] Both exceptions were responses to potash applications.

capability exists, however a different approach may be necessary in Brazil's Northeastern and Western areas. These areas may require basic research to over come serious soil problems before adaptive research would be worthwhile.

CHAPTER VII

CONCLUSIONS AND RESEARCH RECOMMENDATIONS

The objectives of this study were: (1) to estimate the value of marginal product of fertilizer application; (2) review Brazil's fertilizer policy; and (3) suggest policy changes and research priorities based on the findings in (1) and (2).

The use of fertilizer has increased an annual rate of 35 percent in Brazil during the last four years. The region of Ribeirao Preto has been among the leaders in fertilizer usage and the adoption process has been completed in the region as only two of the 174 sample farms did not use fertilizer. The region has been dynamic on the output side also as the enterprise mix has changed in response to changes in the price relationships.

Conclusions

Many of the factors which can restrict the use of fertilizer are not present in the Ribeirao Preto region. Marketing facilities have increased rapidly in recent years and appear to be sufficient for delivery of fertilizer to the farms. There is no problem of awareness of f rtilizer by the farmers in the region as nearly all farmers in the sample used fertilizer. Credit for fertilizer

purchases is also available from banks, fertilizer dealers and cooperatives. The cost of nonbank credit is much higher than bank credit, however it is not excessively high in real terms. Thus, the preconditions for profitable fertilizer usage are present except for the response of yield.

The use of fertilizer was generally not profitable in the region. The negative response to nitrogen was the major cause of the lack of response to all fertilizer as potash normally yielded high positive returns and returns to phosphate varied from negative to positive.

Subsamples of specific locations and fertilizer use levels revealed some differences, particularly with regard to level of application. Higher fertilizer application levels yielded values of the marginal product which were greater than those at low fertilizer use levels. Usage of potash and phosphate yielded postive net returns in many cases at the high use levels.

Factors which may be inhibiting a positive net return to fertilizer in this region are:

1. Application of nitrogen in the form of NH_3SO_4 may increase very rapidly the acidity of soils which are initially acid soils.

2. Heavy rainfall may "leech out" nitrogen before plants have an opportunity to use it.

3. Lack of rainfall at the proper time may cause fertilizer to "burn" crops.

4. Lack of micronutrients and/or presence of micro-organisms in the soil.

5. The present seed varieties may have low response to fertilizer.

6. Improper application methods and nutrient proportions.

7. The present use levels may be insufficient to obtain a significant response.

Comparison of general recommended levels, actual levels, and optimum use levels of fertilizer revealed that the farmers in the area were using levels nearer the optimum than were the recommended levels. The implication of this result is two fold: (1) generalized fertilizer recommendations have little applicability and (2) farmers can determine profitable fertilization rates through their own experience. The continued use of one nutrient, nitrogen, when it yielded negative returns was puzzling. A possible explanation for this phenomenia is that farmers base their decision partially upon their own experience and partly on outside sources. As nitrogen application is stressed by the extension service, the dealers, the fertilizer industry, by the official credit institutions and in many cases fertilizer is sold in a fixed formula which contains a small percentage of nitrogen, it is possible to understand how a farmer may be persuaded to use nitrogen.

These results from one of the most progressive and productive regions in Brazil have serious implications for other less developed areas within Brazil. It is doubtful that higher and more profitable responses to fertilizers will be achieved in these areas than in the state of Sao Paulo. Yet if the income of farmers in poor areas of Brazil is to be increased, higher levels of productivity must be achieved through the use of fertilizer, new crop varieties, defensives etc.. Credit and price programs will have little effect on production and income unless the technological barrier is broken. This type of technological barrier is particularly important in small farm agriculture as fertilizer and seeds are divisible and normally does not exhibit economies of scale.

Research Recommendations

Agronomic research of crop response to fertilization is necessary on the basic and adaptive levels in the Ribeirao Preto region. The negative and insignificant responses to nitrogen require basic research on the soils of the region to identify and solve this problem. This may also require research to develop new crop varieties which are more responsive to fertilization.

The agronomic problems of fertilizer use in Brazil may require a different type of strategy. The problems in the Ribeirao Preto region may be solveable by present organizations in Sao Paulo, but

perform the same function on a national scale may require a concentration of research by physical and social scientists. Their coordinated efforts should be devoted to gathering, reviewing and analyzing the presently available data and designing and carrying out new research projects to fill the information gaps.

In addition to the research which is primarily agronomic, there are several issues which are in the realm of economics. An evaluation of Brazil's fertilizer program with regard to its benefits and costs needs to be undertaken. This analysis should consider alternative programs such as focusing the fertilizer program at the extensive margin, i. e., areas which fertilizer is not presently used, or concentrating on agronomic research. There are also several other minor questions to be answered. How and where are recommended fertilization rates determined? What are the possibilities to use on-farm experimental plots to generate recommended rates? How important are soil and climate differences within regions with respect to the economics of fertilizer use? Is there a quality control problem within the marketing system? Does there exist a lack of information on optimum methods of applying fertilizer?

As millions of dollars have been spent to grant price and credit concessions for fertilizer without adequate knowledge of their payoffs, it would be economically desirable to transfer a portion of

these funds to determine the effect of past expenditures and to investigate ways to increase the profitability of fertilizer utilization in the future.

APPENDIX A

TERMS AND MEASURES

TERMS AND MEASURES

Agronomo: A college graduate with a degree equivalent to a B.S. in general agricuture, often has a role similar to a county extension agent.

Alqueire (alq.): A unit of land measurement which is approximately equal to 2.42 hectares or 5.98 acres.

Arroba (arr.): A unit of weight which is equal to 15 kg. or 33 pounds.

Cruzeiro (Cr$): A unit of value, Cr$ 4.25 was approximately equal to US$ 1.00 during 1969/70.

Hectare (ha.): A unit of land measurement which is approximately equal to 2.47 acres or 0.41 alqueires.

Kilogram (Kg.): A unit of weight which is approximately equal to 2.2 pounds.

Millimeter (mm): A unit of length which is approximately equal to 0.39 inches.

Saco (s.): A unit of weight which is equal to 60 kg.

APPENDIX B

FARM QUESTIONNAIRE

APPENDIX C

INFRASTRUCTURE QUESTIONNAIRES

APPENDIX D

CALCULATION OF INDICES

Calculation of Management and Information

Source

Interviews with three extension agents, 16 fertilizer dealers and 16 bankers were used to develop these indices. The infrastructure questionnaires (Appendix C) present the questions asked each of the respondents.

Calculation of Weights

Each respondent was asked to rank eight management factors and eleven information sources, in order of their importance to management ability and value of information, respectively. The respondents were then requested to indicate the relative difference between the factor which they ranked first and the last ranked factor, five times as important, ten times, etc.. An average of the responses was computed for each index and was linearly distributed according to the number of items in the index (Table 27). The average of the responses with respect to management, for example, was 26.25; thus a factor ranked first receives a weight of 26.25, the second, 22.50, etc.

Calculation of Coefficients

The coefficients for each of the factors were computed by summing the number of times a factor was ranked first times the weight given to a first place ranking plus the number of times the

TABLE 27.--Weighting factors for the components of the management and information indices

Management		Information	
Rank	Weight	Rank	Weight
1	26.25	1	41.00
2	22.50	2	36.90
3	18.75	3	32.80
4	15.00	4	28.70
5	11.25	5	24.60
6	7.50	6	20.50
7	3.75	7	16.40
8	.00	8	12.30
		9	8.20
		10	4.10
		11	.00

factor was ranked second times the weight given to a second place rank, ... , plus the number of times the factor was ranked last times the weight given to the least important factor. This procedure was duplicated for each component of the index. Then the summation of the subtotals of each factor was divided into the subtotal of each factor to obtain a ratio (Table 28). The

TABLE 28.--Coefficients for management and information indices

	Factors	Fertilizer Dealers	Banks	Extension Agents	Average
Management Weights					
1	Experience	.1696	.1905	.1080	.1734
2	Education	.1560	.2002	.1428	.1742
3	Insurance	.0714	.0452	.0476	.0578
4	Records	.1160	.0546	.1778	.0944
5	Ag. Organizations	.0870	.0692	.1080	.0810
6	Agric. Information	.1120	.1308	.1555	.1242
7	Credit	.1452	.1594	.1778	.1544
8	Analysis of Soils	.1428	.1500	.0825	.1406
Information Weights					
1	Newspapers	.0785	.0692	.0782	.0742
2	Private Extension	.1375	.0954	.0974	.1148
3	Radio	.0854	.0762	.0606	.0790
4	Banks	.0648	.0727	.0428	.0666
5	Demonstrations & Experiments	.0828	.1000	.1448	.0960
6	Fairs	.0876	.1000	.1094	.0952
7	Govern. Extension	.1396	.1658	.1758	.1546
8	Agric. Magazines	.0943	.1136	.0916	.1028
9	Coop Extension	.0943	.1126	.1212	.1050
10	TV	.0670	.0296	.0236	.0462
11	Pamphlets	.0682	.0648	.0546	.0656

summation of the value of these ratios equal 1.00 for each index.

Calculation of Farmer Indices

The index value for a farmer was calculated by two methods. One set of indices (management and information) was based on a presence or absence concept. For example, the weight of 174 would be included in his management index if he had more than an elementary education. If he has less than an elementary education, he would receive 174 for an elementary education, 348 (174:2 for a junior high, 522 (174:3 for high school and 696 (174:4 for a college education. The system for computing individual farmer indices is given in Table ২৭.

TABLE 29.--Calculation of Farmer Indices

Requirement		Multiplier	Coefficient
Management I			
1. Experience:	10 years	1	174
2. Education:	5 years	1	174
3. Insurance:	Usage	1	48
4. Records:	Usage	1	94
5. Ag. Organizations:	Member	1	81
6. Ag. Information:	Usage	1	24
7. Credit:	Usage	1	54
8. Soil Analysis:	Usage	1	141
Possible Total			1000
Management II			
1. Experience:	0 years	0	174
	1-10 years	1	
	11-20 years	2	
	21-30 years	3	
	31 years	4	
2. Education:	0 years	0	174
	1-4 years	1	
	5-8 years	2	
	9-12 years	3	
	13 years	4	
3. Insurance:	No Usage	0	58
	Usage	4	
4. Records:	No Usage	0	94
	Partial Usage	2	
	Complete Usage	4	
5. Ag. Organization:	Non-member	0	81
	Member	4	
6. Ag. Information:	None	0	124
	One Source	2	
	Two Sources	4	
7. Credit:	0 loans	0	154
	1-5 loans	1	
	6-10 loans	2	
	11-15 loans	3	
	16 loans	4	

TABLE 29 --Continued

Requirement		Multiplier	Coefficient
4. Banks:	0 contacts/year	0	67
	1-29 contacts/year	1	
	30-59 contacts/year	2	
	60-97 contacts/year	3	
	98 contacts/year	4	
5. Demonstrations:	0 contacts/yr.	0	96
	1-29 contacts/yr.	2	
	30-59 contacts/yr.	2	
	60-97 contacts/yr.	3	
	98 contacts/yr.	4	
6. Fairs:	0 contacts/yr.	0	95
	1-29 contacts/year	1	
	30-59 contacts/year	2	
	60-97 contacts/year	3	
	98 contacts/year	4	
7. Govern. Extension:	0 contacts/yr.	0	155
	1-29 contacts/yr.	1	
	30-59 contacts/yr.	2	
	60-97 contacts/yr.	3	
	98 contacts/yr.	4	
8. Agric. Magazines:	0 copies/year	0	103
	1-29 copies/year	1	
	30-59 copies/year	2	
	60-97 copies/year	3	
	98 copies/year	4	
9. Coop Extension:	0 contacts/yr.	0	105
	1-29 contacts/yr.	1	
	30-59 contacts/yr.	2	
	60-97 contacts/yr.	3	
	98 contacts/yr.	4	
10. Television:	Not own	0	46
	Own	4	
11. Pamphlets:	0 items/year	0	66
	1-29 items/year	1	
	30-59 items/year	2	
	60-97 items/year	3	
	98 items/year	4	
Possible Total			4000

TABLE 29--Continued

Requirement	Multiplier	Coefficient
8. Soil Analysis: Never	0	141
1-49% of Area	1	
20-59% of Area	2	
60-99% of Area	3	
100% of Area	4	
Possible Total		1000
Information I		
1. Newspapers: Read	1	74
2. Private Extension: Contact	1	115
3. Radio: Own	1	79
4. Banks: Contact	1	67
5. Demonstrations: Contact	1	96
6. Fair: Contact	1	95
7. Govern. Extension: Contact	1	155
8. Agricultural Magazines: Read	1	103
9. Coop Extension: Contact	1	105
10. Television: Own	1	46
11. Pamphlets: Read	1	66
Possible Total		1000
Information II		
1. Newspapers: 0 copies/year	0	74
1-99 copies/year	1	
100-199 copies/year	2	
200-299 copies/year	3	
300 copies/year	4	
2. Private Extension: 0 contacts/yr.	0	115
1-29 contacts/yr.	1	
30-59 contacts/yr.	2	
60-97 contacts/yr.	3	
98 contacts/yr.	4	
3. Radio: Not own	0	79
Own	4	

APPENDIX E

NATIONAL FERTILIZER DATA

TABLE 30.--Consumption and production of fertilizer by region, Brazil, 1950 - 1970

	Total	South	Center	North
1970[a]				
Nitrogen				
Phosphorus				
Potassium				
Total	820.0			
% National	20.0			
1969				
Nitrogen	164.4	27.2	120.8	16.4
Phosphorus	265.7	80.8	167.4	17.4
Potassium	200.3	43.1	138.5	18.6
Total	630.4	151.2	426.8	52.5
% National	21.0	8.6	27.0	8.0
1968				
Nitrogen	144.3	21.0	110.9	12.4
Phosphorus	273.1	69.0	190.3	13.7
Potassium	184.3	33.3	138.7	12.3
Total	601.7	133.7	439.9	38.4
% National	22.0	8.3	26.5	12.0
1967				
Nitrogen	103.4	13.2	82.5	10.7
Phosphorus	204.6	54.6	137.2	12.8
Potassium	136.9	17.6	102.3	17.0
Total	444.9	85.4	322.0	40.6
% National	26.0	13.6	39.6	16.0

[a]Data by type and region is not available for 1970.

TABLE 3a - Continued

	Total	South	Center	North
1966				
Nitrogen	71.1	7.2	56.3	7.6
Phosphorus	116.6	19.2	86.1	11.3
Potassium	93.3	11.2	73.0	9.2
Total	281.1	37.5	215.5	28.1
% National	32.0	21.4	35.6	30.3
1965				
Nitrogen	70.6	6.3	60.5	3.8
Phosphorus	120.1	25.4	25.0	9.7
Potassium	99.7	11.3	80.8	7.6
Total	290.4	43.0	226.3	21.2
% National	34.0	21.6	35.8	33.1
1964				
Nitrogen	50.8	6.0	39.6	5.2
Phosphorus	135.1	28.1	96.0	10.9
Potassium	69.6	8.7	54.4	6.5
Total	255.4	42.8	190.0	22.6
% National	42.0	31.3	45.3	38.7
1963				
Nitrogen	65.2	7.7	51.6	5.9
Phosphorus	156.8	36.0	110.6	10.3
Potassium	92.1	12.3	71.4	8.3
Total	314.0	56.0	233.6	24.5
% National	35.0	19.9	40.2	28.6
1962				
Nitrogen	50.9	6.0	40.7	4.1
Phosphorus	117.5	19.6	86.7	11.2
Potassium	68.4	8.5	54.0	5.9
Total	236.8	34.1	181.5	21.3
% National	41.0	20.3	46.5	37.8

TABLE 30--Continued

	Total	South	Center	North
1961				
Nitrogen	56.8	6.4	47.4	3.0
Phosphorus	118.4	23.0	84.2	11.1
Potassium	13.0	9.6	56.8	5.5
Total	248.1	39.0	188.4	19.7
% National	39.0	20.9	41.9	44.9
1960				
Nitrogen	64.7	6.5	53.3	4.9
Phosphorus	127.7	39.0	75.7	12.9
Potassium	106.3	13.0	87.5	5.7
Total	298.7	58.5	216.5	23.7
% National	35.0	28.0	34.9	48.1
1959[b]				
Nitrogen	44.8			
Phosphorus	124.0			
Potassium	57.4			
Total	226.2			
% National	35.0			
1958				
Nitrogen	41.4			
Phosphorus	143.3			
Potassium	65.0			
Total	249.7			
% National	22.5			

[b]Data by region is not available prior to 1960.

TABLE 30--Continued

	Total	South	Center	North
1957				
Nitrogen	28.6			
Phosphorus	118.7			
Potassium	60.2			
Total	207.5			
% National	20.5			
1956				
Nitrogen	30.2			
Phosphorus	93.5			
Potassium	41.6			
Total	165.3			
% National	15.0			
1955				
Nitrogen	22.9			
Phosphorus	88.6			
Potassium	49.5			
Total	161.0			
% National	15.5			
1954				
Nitrogen	17.8			
Phosphorus	77.4			
Potassium	28.3			
Total	123.5			
% National	10.8			
1953				
Nitrogen	20.6			
Phosphorus	64.8			
Potassium	31.2			
Total	116.6			
% National	15.3			

TABLE 30--Continued

	Total	South	Center	North
1952				
Nitrogen	10.6			
Phosphorus	46 9			
Potassium	15.3			
Total	72.8			
% National	22.9			
1951				
Nitrogen	18.6			
Phosphorus	73.6			
Potassium	28.7			
Total	120.9			
% National	11.6			
1950				
Nitrogen	14.2			
Phosphorus	50.8			
Potassium	23.5			
Total	88.5			
% National	15.2			

Source: 1960-1970: Associacao Nacional Para Difusao De Adubos, Estatisticas Sobre O Consumo De Fertilizantes No Brasil (Sao Paulo, October, 1970).

1950-1959: Banco Nacional Do Desenvolvimento Economica, Mercado Brasileiro Do Fertilizantes - 1950-1970 (Rio de Janeiro, August, 1965).

ABLE 31.--Indices of fertilizer and crop prices, and the ratio of fertilizer prices to crop prices, 1950-1970

Year	Index of Fertilizer Prices	Index of Crop Prices	Ratio of Fertilizer to Crop Indices
1970	13,321	18,240	.73
1969	12,546	16,349	.76
1968	10,970	12,833	.85
1967	8,358	10,965	.76
1966	7,998	9,860	.81
1965	8,001	6,492	1.23
1964	4,347	4,500	.97
1963	2,152	2,415	.89
1962	1,229	1,465	.84
1961	687	895	.77
1960	343	628	.55
1959	230	438	.52
1958	220	318	.70
1957	203	291	.70
1956	205	264	.78
1955	178	221	.80
1954	128	171	.72
1953	105	155	.68
1952	114	124	.92
1951	108	109	.99
1950	94	93	1.01

Source: Instituto De Economia Agricola, Desenvolvimento Da Agricultural Paulista, (Sao Paulo: Secretaria da Agricultura, March, 1971).

TABLE 32.--Prices of nitrogen, phosphate and potassium, Brazil, 1950-1970

Year	Nitrogen (Ncr$/ton)	Phosphorus (P_2O_5) (Ncr$/ton)	Potassium (K_2O) (Ncr$/ton)
1970	237.9	205.9	278.2
1969	216.0	180.0	236.0
1968	193.0	155.0	193.0
1967	170.0	130.0	150.0
1966	189.0	123.0	182.0
1965	209.0	117.0	214.0
1964	131.0	79.0	136.0
1963	53.0	41.0	58.0
1962	45.8	32.1	51.0
1961	25.7	17.6	30.4
1960	13.7	12.0	16.2
1959	8.1	4.6	8.2
1958	8.2	4.4	5.1
1957	5.6	3.5	4.8
1956	4.7	3.2	4.6
1955	4.9	2.9	4.8
1954	4.5	2.6	4.2
1953	3.2	1.8	3.0
1952	2.6	1.6	2.3
1951	2.8	1.8	2.5
1950	2.7	1.6	2.5

Source: Instituto de Economia Agricola, Agricultura em Sao Paulo, various issues, (Sao Paulo: Secretaria da Agricultura, 1960-1970)

TABLE 33.--Agricultural credit and interest rates, Brazil, 1950-1970

Year	Agricultural[a] Credit (1000,000 NCr$)	FUNFERTIL Credit (1000 NCr$)	Interest Rate[b] (A)	(B)	Inflation Rate
1970	4,414	100	7	15.0	.
1969	3,077	203	0	15.0	19.2
1968	2,767	233	0	16.0	24.2
1967	1,544	141	0	17.0	22.0
1966	979	23	0	17.2	41.6
1965	954		13	18.0	31.4
1964	490		13	17.7	84.1
1963	237		7	13.2	83.1
1962	135		7	12.4	45.8
1961	75		7	11.5	53.0
1960	51		7	10.3	34.5
1959	38		7	8.5	35.8
1958	25		7	8.8	35.6
1957	19		7	10.4	3.8
1956	14		7	9.8	25.8
1955	13		7	11.0	16.3
1954	10		7	10.9	22.0
1953	5		7	9.4	23.2
1952	4		7	9.4	10.7
1951	3		7	8.4	17.6
1950	0				

[a]Balance at December 31 for agricultural production credit from all banks.

[b]Interest rate (A) is based on minimum rates of the Bank of Brazil and interest rate (B) is an average rate computed by F. R. Reis.

Source: Instituto Brasileiro Geografico e Estatistico, Anuario Estatistico do Brasil, various issues, (Rio de Janeiro: Conselho Nacional de Estatistica, 1960-1970).

Sources continued: Banco do Brasil, unpublished documents of the FUNFERTIL program, (Rio de Janeiro, 1971).

Fernando Roquette Reis, "Credito Rural Para Todos," Guia da Commercializacao Rural, (Coopercotia, 1970), pp. 56-68.

TABLE 34.--Cultivated area and yield index, Brazil, 1950-1970

Year	Cultivated Area (1000 ha.)	Index of Yield[a]
1970	a	136
1969	34,600	131
1968	33,438	124
1967	32,763	136
1966	30,719	132
1965	32,609	136
1964	30,773	102
1963	29,842	122
1962	28,506	113
1961	27,329	122
1960	26,370	112
1959	24,773	139
1958	23,702	119
1957	23,303	115
1956	22,792	95
1955	21,877	100
1954	20,944	95
1953	19,665	103
1952	a	102
1951	a	97
1950	19,100	93

[a]Data is not available for these years.

Source: Instituto Brasileiro Geografico e Estatistico, Anuario Estatistico do Brasil, various issues, (Rio de Janeiro: Conselho Nacional de Estatistica, 1964-1970).

Instituto de Economia Agricola, Agricultura em Sao Paulo, various issues, (Sao Paulo: Secretaria da Agricultura, 1960-1970).

APPENDIX F

MEANS OF VARIABLES

Table 35 Arithmetic Mean Values of Aggregate Production Variables by Total and Location

Variables[a]	Total Sample	Guaira	Jard-Sales	Other Areas
Y_5 = Aggregate Yield (corn equivalents)	123.75	138.50	125.25	100.10
X_1 = Lime (tons/alq)	3.98	5.57	3.38	2.73
X_2 = Nitrogen (kg/alq)	30.14	31.00	26.00	42.50
X_3 = Phosphate (kg/alq)	111.86	115.50	99.50	94.20
X_4 = Potash (kg/alq)	58.41	78.50	27.50	49.00
X_5 = Total NPK (kg/alq)	197.40	224.00	153.00	185.70
X_6 = Labor (Cr$/alq)	231.89	304.78	188.68	175.30
X_7 = Seed & Defensives (Cr$/alq)	90.90	130.54	83.17	79.67
X_8 = Machinery (Cr$/alq)	278.98	271.81	220.82	394.25
X_9 = Labor & Machinery (Cr$/alq)	510.87	576.59	409.50	569.55
X_{10} = Operating Expense (Cr$/alq)	601.77	708.94	543.07	601.04
X_{11} = Management Index II (0-4000)	1774.40	1821.48	1739.45	1750.21
X_{12} = Crop/Cultivated Area (0.00)	0.79	0.87	0.69	0.64
X_{13} = Crop Land (alq)	46.61	64.12	27.32	33.15
Farm Size in Cultivated Area (alq)	55.84	73.73	39.62	51.80
Number of Observations	151	60	58	33

[a] One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 36 Geometric Mean Values of Aggregate Production Variables by Total and Location

Variables[a]	Total Sample	Guaira	Jard-Sales	Other Areas
Y_5 = Aggregate Yield (corn equivalents)	124.00	139.00	127.00	100.00
X_1 = Lime (tons/alq)	3.98	5.21	3.39	2.79
X_2 = Nitrogen (kg/alq)	15.50	16.00	12.75	21.00
X_3 = Phosphate (kg/alq)	52.00	58.00	50.00	47.00
X_4 = Potash (kg/alq)	23.50	39.50	14.00	24.50
X_5 = Total NPK (kg/alq)	115.00	130.00	105.00	107.00
X_6 = Labor (Cr$/alq)	103.00	100.00	106.00	104.00
X_7 = Seed & Defensives (Cr$/alq)	54.00	78.50	52.00	29.50
X_8 = Machinery (Cr$/alq)	209.00	224.00	164.00	276.00
X_9 = Labor & Machinery (Cr$/alq)	383.00	396.00	337.00	459.00
X_{10} = Operating Expense (Cr$/alq)	437.00	474.50	489.00	488.00
X_{11} = Management Index II (0-4000)	1610.00	1530.00	1640.00	1660.00
X_{12} = Crop/Cultivated Area (0.00)	0.74	0.87	0.68	0.65
X_{13} = Crop Land (alq)	20.50	27.10	15.20	20.30
Farm Size in Cultivated Area	27.40	31.10	22.20	31.50
No. of Observations	151	60	58	33

[a]One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 37 Arithmetic Mean Values of Corn Production Variables by Total, Level of Fertilizer Use and Location

Variables[b]	Total Sample	Sample A High[a] NPK	Sample A Low NPK	Guaira	Jard-Sales	Other
Y_3 = Corn Yield (60 kg/alq)	106.50	112.19	103.27	107.88	108.81	97.85
X_1 = Lime (tons/alq)	5.12	1.25	6.87	11.56	0.93	0.78
X_2 = Nitrogen (kg/alq)	34.10	66.02	19.67	30.92	29.72	47.57
X_3 = Phosphate (kg/alq)	80.49	114.60	65.08	81.43	82.67	74.94
X_4 = Potash (kg/alq)	51.48	71.28	42.53	69.65	37.93	42.24
X_5 = Total NPK (kg/alq)	166.07	251.89	127.28	182.00	150.33	164.76
X_6 = Labor (Cr$/alq)	231.89	147.85	269.88	304.78	188.68	175.30
X_7 = Seed and Defensives (Cr$/alq)	32.63	36.04	31.08	32.35	33.57	31.48
X_8 = Machinery (Cr$/alq)	278.98	313.22	263.51	271.81	220.82	394.25
X_9 = Labor and Machinery (Cr$/alq)	510.87	461.07	533.39	576.59	409.50	569.55
X_{10} = Operating Expenses (Cr$/alq)	543.49	497.11	564.47	608.94	443.07	601.04
X_{11} = Management Index (0-4000)	1774.40	1892.32	1721.10	1821.48	1739.45	1750.21
X_{12} = Crop/Cultivated Area (0.00)	0.420	0.404	0.428	0.408	0.433	0.423
X_{13} = Crop Land (alq)	18.37	22.08	16.69	19.53	16.01	20.39
Farm Size in Cultivated Area (alq)	55.84	73.37	47.01	73.73	39.62	51.80
No. of Observations	151	47	104	60	58	33

[a]Nitrogen ≥ 50 kg/alq or Phosphate ≥ 100 kg/alq or Potash ≥ 100 kg/alq

[b]One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 37 Arithmetic Mean Values of Corn Production Variables by Total, Level of Fertilizer Use and Location

Variables	All	Sample B High	Low	Others
Y_3 = Corn Yield (60 kg/alq)	108.96	128.67	92.96	96.32
X_1 = Lime (tons/alq)	22.55	10.56	32.28	134.17
X_2 = Nitrogen (kg/alq)	32.66	41.26	25.68	46.45
X_3 = Phosphate (kg/alq)	105.14	145.30	72.57	2.32
X_4 = Potash (kg/alq)	68.77	95.88	46.77	2.02
X_5 = Total NPK (kg/alq)	206.57	282.44	145.02	50.80
X_6 = Labor (Cr$/alq)	248.63	378.33	143.41	195.06
X_7 = Seed and Defensives (Cr$/alq)	33.85	35.60	32.43	30.35
X_8 = Machinery (Cr$/alq)	288.45	342.56	244.55	270.74
X_9 = Labor & Machinery (Cr$/alq)	537.08	720.89	387.96	465.80
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II (0-4000)	1900.70	1852.91	1939.47	1511.88
X_{12} = Crop/Cultivated Area (0.00)	0.041	0.35	0.46	0.47
X_{13} = Crop Land (alq)	20.34	22.34	18.72	17.98
Farm Size in Cultivated Area (alq)	64.83	83.86	49.39	45.54
No. of Observations	96	43	53	40

Table 38 Geometric Values of Corn Production Variables by Total, Level of

Variable[b]	Total Sample	Sample A: High[a]	Low	Guaira	Jard-Sales	Other
Y_3 = Corn Yield (60 kg/alq)	98.00	104.00	95.00	100.00	102.00	88.00
X_1 = Lime (tons/alq)	2.75	3.22	2.53	3.82	2.18	2.23
X_2 = Nitrogen (kg/alq)	14.00	28.00	10.00	15.00	9.88	24.00
X_3 = Phosphate (kg/alq)	30.00	34.00	11.00	33.00	27.50	32.00
X_4 = Potash (kg/alq)	16.00	14.50	16.00	25.00	8.94	19.00
X_5 = Total NPK (kg/alq)	96.00	219.00	65.00	103.00	80.00	113.00
X_6 = Labor (Cr$/alq)	103.00	93.00	108.00	100.00	106.00	104.00
X_7 = Seed & Defensives Cr$/alq)	29.00	31.00	28.00	29.00	31.00	28.00
X_8 = Machinery (Cr$/alq)	209.00	219.00	203.00	224.00	164.00	276.00
X_9 = Labor & Machinery (Cr$/alq)	383.00	380.00	388.00	396.00	337.00	459.00
X_{10} = Operating Expenses	420.00	420.00	424.00	433.00	376.00	498.00
X_{11} = Management Index (0-4000)	1610.00	780.00	530.00	530.00	1660.00	1660.00
X_{12} = Crop/Cultivated Area (0.00)	0.34	0.35	0.34	0.32	0.41	0.34
X_{13} = Crop Land (alq)	9.40	12.00	6.70	9.90	8.20	10.80
Farm Size in Cultivated Area (alq)	27.40	35.10	24.50	31.10	22.20	31.40
No. of Observations	151	47	104	60	54	33

[a]Nitrogen ≥ 50 kg/alq or Phosphate ≥ 100 kg/alq or Potash ≥ 100 kg/alq.

[b]One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 38 Geometric Values of Corn Production Variables by Total, Level of Fertilizer Use and Location

Sample B

Variables	All	High	Low	Other
Y_3 = Corn Yield (60 kg/alq)	100.00	121.00	85.00	91.00
X_1 = Lime (tons/alq)	2.72	2.89	2.61	2.56
X_2 = Nitrogen (kg/alq)	26.00	32.00	21.00	7.17
X_3 = Phosphate (kg/alq)	93.00	136.00	68.00	1.48
X_4 = Potash (kg/alq)	59.00	85.00	44.00	1.38
X_5 = Total NPK (kg/alq)	187.00	268.00	139.00	15.00
X_6 = Labor (Cr$/alq)	100.00	115.00	88.00	107.00
X_7 = Seed & Defensives (Cr$/alq)	29.00	32.00	28.00	27.00
X_8 = Machinery (Cr$/alq)	233.00	308.00	185.00	159.00
X_9 = Labor & Machinery (Cr$/alq)	388.00	473.00	330.00	373.00
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II (0-4000)	1710.00	1760.00	1660.00	1420.00
X_{12} = Crop/Cultivated Area (0.00)	0.33	0.28	0.38	0.39
X_{13} = Crop Land (alq)	11.90	11.70	10.10	8.20
Farm Size in Cultivated Area (alq)	32.40	41.20	26.50	21.30
No. of Observations	96	43	53	40

Table 39 Arithmetic Mean Values of Rice Production Variables by Total, Level of Fertilizer Use and Location

Variables[b]	Total Sample	Sample A High[a]	Sample A Low	Guaira	Jard-Sales	Other
Y_2 = Rice Yield (60 kg/ha)	68.76	68.97	68.67	61.89	76.70	64.38
X_1 = Lime (tons/alq)	2.08	0.92	2.97	1.59	0.27	6.50
X_2 = Nitrogen (kg/alq)	16.84	32.74	9.74	19.81	16.15	13.88
X_3 = Phosphate (kg/alq)	74.47	147.97	41.59	78.78	72.00	72.81
X_4 = Potash (kg/alq)	31.79	50.97	23.21	36.00	29.88	29.27
X_5 = Total NPK (kg/alq)	123.11	231.68	74.54	134.59	118.02	115.96
X_6 = Labor (Cr$/alq)	507.21	429.98	541.76	503.81	403.82	698.93
X_7 = Seed & Defensives (Cr$/alq)	55.50	107.71	32.14	98.89	37.13	26.96
X_8 = Machinery (Cr$/alq)	282.98	292.22	278.86	293.68	223.66	375.03
X_9 = Labor & Machinery (Cr$/alq)	790.19	722.20	820.62	797.49	627.48	1073.96
X_{10} = Operating Expenses (Cr$/alq)	845.69	829.91	852.76	896.38	666.46	1100.92
X_{11} = Management Index (0-4000)	1765.42	1860.24	1723.00	1677.03	1782.60	1860.15
X_{12} = Crop/Cultivated (0.00)	0.200	0.147	0.208	0.132	0.179	0.289
X_{13} = Crop Land (alq)	9.00	7.28	9.78	8.25	6.65	14.35
Farm Size in Cultivated Area (alq)	57.11	67.59	52.43	93.60	34.53	46.01
Number of Observations	110	34	76	37	47	26

[a]Nitrogen ≥ 50 kg/alq or Phosphate ≥ 100 kg/alq or Potash ≥ 100 kg/alq

[b]One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 39 Arithmetic Mean Values of Rice Production Variables by Total, Level of Fertilizer Use and Location

Variables	Sample B High	Medium	Low
Y_2 = Rice Yield (60 kg/alq)	62.46	64.50	81.76
X_1 = Lime (tons/alq)	293.98	11.17	166.44
X_2 = Nitrogen (kg/alq)	24.48	2.50	11.41
X_3 = Phosphate (kg/alq)	93.52	149.17	2.44
X_4 = Potash (kg/alq)	55.10	3.44	7.03
X_5 = Total NPK (kg/alq)	173.10	155.11	20.88
X_6 = Labor (Cr$/alq)	408.51	453.98	703.75
X_7 = Seed and Defensives (Cr$/alq)	71.40	41.50	39.03
X_8 = Machinery (Cr$/alq)	295.85	284.20	260.41
X_9 = Labor and Machinery (Cr$/alq)	704.36	738.18	964.17
X_{10} = Operating Expenses (Cr$/alq)			
X_{11} = Management Index II (0-4000)	1796.98	1773.11	707.50
X_{12} = Crop/Cultivated Area (0.00)	0.19	0.17	0.19
X_{13} = Crop Land (alq)	8.13	4.92	12.67
Farm Size in Cultivated Area	60.98	27.80	66.03
No. of Observations	58	18	34

Table 40 Geometric Values of Rice Production Variables by Total, Level of Fertilizer Use and Location

Variable[b]	Total Sample	Sample A High[a]	Low	Guiara	Jard-Sales	Others
Y_2 = Rice Yield (60 kg/alq)	59.00	59.00	58.00	54.00	65.00	55.00
X_1 = Lime (tons/alq)	2.07	2.27	2.00	2.75	1.24	3.56
X_2 = Nitrogen (kg/alq)	6.43	14.50	4.49	6.89	5.64	7.39
X_3 = Phosphate (kg/alq)	25.00	85.00	14.50	21.00	23.00	35.00
X_4 = Potash (kg/alq)	9.77	17.00	7.77	10.50	9.03	15.00
X_5 = Total NPK (kg/alq)	58.00	209.00	32.00	54.00	53.00	72.00
X_6 = Labor (Cr$/alq)	245.00	271.00	235.00	296.00	255.00	171.00
X_7 = Seed and Defensives (Cr$/alq)	29.00	39.00	26.50	26.00	40.00	19.50
X_8 = Machinery (Cr$/alq)	222.00	250.00	211.00	265.00	166.00	293.00
X_9 = Labor and Machinery (Cr$/alq)	584.00	620.00	567.00	666.00	529.00	579.00
X_{10} = Operating Expenses (Cr$/alq)	627.00	686.00	602.00	721.00	567.00	614.00
X_{11} = Management Index (0-4000)	1680.00	1780.00	1625.00	1550.00	1690.00	1820.00
X_{12} = Crop/Cultivated Area (0.00)	0.14	0.12	0.16	0.105	0.155	0.225
X_{13} = Crop Land (alq)	4.30	3.40	4.70	4.30	3.20	8.40
Farm Size in Cultivated Area (alq)	29.30	28.20	29.60	41.20	20.90	32.70
No. of Observations	110	34	76	37	47	26

[a] Nitrogen ≥ 50 kg/alq or Phosphate ≥ 100 kg/alq or Potash ≥ 100 kg/alq.

[b] One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 40 Geometric Values of Rice Production Variables by Total, Level of Fertilizer Use and Location

Variables	Sample B High	Medium	Low
Y_2 = Rice Yield (60 kg/alq)	51.50	58.00	72.50
X_1 = Lime (tons/alq)	2.14	3.07	1.59
X_2 = Nitrogen (kg/alq)	18.50	1.20	2.54
X_3 = Phosphate (kg/alq)	79.00	120.50	1.50
X_4 = Potash (kg/alq)	48.00	1.41	1.88
X_5 = Total NPK (kg/alq)	154.50	1[illegible]7.00	7.03
X_6 = Labor (Cr$/alq)	250.00	255.00	230.50
X_7 = Seed and Defensives (Cr$/alq)	11.00	18.00	14.00
X_8 = Machinery (Cr$/alq)	233.00	215.00	211.00
X_9 = Labor and Machinery (Cr$/alq)	584.00	596.00	578.00
X_{10} = Operating Expenses (Cr$/alq)			
X_{11} = Management Index II (Cr$/alq)	1690.00	1710.00	610.00
X_{12} = Crop/Cultivated Area (0.00)	0.145	0.14	0.14
X_{13} = Crop Land (alq)	4.20	2.90	5.40
Farm Size in Cultivated Area (alq)	28.20	20.90	37.30
No. of Observations	58	18	34

Table 41 Arithmetic Mean Values of Cotton Production Variables by Total, Level of Fertilizer Use and Location

Variables[b]	Total Sample	Sample A: High[a] NPK	Sample A: Low NPK	Guaira	Jard-Sales	Other
Y_1 = Cotton Yield (15 kg/alq)	198.35	221.53	184.98	223.05	190.34	115.40
X_1 = Lime (tons/alq)	3.96	1.66	5.29	0.58	1.71	25.01
X_2 = Nitrogen (kg/alq)	43.96	74.07	26.60	40.46	46.93	50.40
X_3 = Phosphate (kg/alq)	183.51	193.27	177.88	216.40	156.93	119.20
X_4 = Potash (kg/alq)	114.47	129.13	106.02	128.14	98.93	100.80
X_5 = Total NPK (kg/alq)	341.95	396.47	310.50	385.00	302.79	270.40
X_6 = Labor (Cr$/alq)	175.91	146.56	192.84	157.65	167.79	277.96
X_7 = Seed and Defensives (Cr$/alq)	267.32	331.93	230.04	246.16	292.00	286.70
X_8 = Machinery (Cr$/alq)	284.33	267.15	294.24	271.90	238.88	469.60
X_9 = Labor & Machinery (Cr$/alq)	460.24	413.71	487.08	429.55	406.67	747.56
X_{10} = Operating Expenses (Cr$/alq)	727.56	745.64	717.12	675.71	698.67	1034.26
X_{11} = Management Index (0-4000)	1811.23	1976.83	1715.69	1741.32	1968.55	1655.60
X_{12} = Crop/Cultivated Area	0.365	0.364	0.366	0.403	0.338	0.282
X_{13} = Crop Land (alq)	25.55	32.50	21.57	30.86	21.14	15.50
Farm Size in Cultivated Area (alq)	81.26	103.53	69.66	94.13	60.88	85.02
Number of Observations	82	30	52	43	29	10

[a]Nitrogen use ≥ 50 kg/alq or Phosphate ≥ 200 kg/alq or Potash ≥ 200 kg/alq

[b]One alqueire is equal to 2.42 hectares or 5.98 acres

Table 41 Arithmetic Mean Values of Cotton Production Variables by Total, Level of Fertilizer Use and Location

Variables	Sample B High	Sample B Low
Y_1 = Cotton Yield (kg/alq)	216.46	185.46
X_1 = Lime (tons/alq)	144.20	780.74
X_2 = Nitrogen (kg/alq)	52.91	31.91
X_3 = Phosphate (kg/alq)	199.11	106.11
X_4 = Potash (kg/alq)	170.46	97.40
X_5 = Total NPK (kg/alq)	422.48	235.43
X_6 = Labor (Cr$/alq)	166.61	201.44
X_7 = Seed & Defensives (Cr$/alq)	280.28	240.20
X_8 = Machinery (Cr$/alq)	272.08	292.08
X_9 = Labor & Machinery (Cr$/alq)	438.69	493.53
X_{10} = Operating Expenses (Cr$/alq		
X_{11} = Management Index (0-4000)	1802.60	809.71
X_{12} = Crop/Cultivated Area (0.00)	0.38	0.32
X_{13} = Crop Land (alq)	31.01	22.13
Farm Size in Cultivated Area	89.17	86.20
No. of Observations	35	35

Table 42 Geometric Values of Cotton Production Variables by Total, Level of Fertilizer Use and Location

Variable[b]	Total Sample	Sample A High[a]	Sample A Low	Guaira	Jard-Sales	Other
Y_1 = Cotton Yield (kg/alq)	185.00	209.00	174.00	215.00	184.00	103.00
X_1 = Lime (tons/alq)	3.94	4.96	3.46	3.26	5.88	2.75
X_2 = Nitrogen (tons/alq)	26.50	41.50	21.00	25.00	25.80	37.50
X_3 = Phosphate (kg/alq)	102.00	116.00	95.00	106.00	106.00	77.50
X_4 = Potash (kg/alq)	59.00	41.50	73.00	75.00	41.50	65.50
X_5 = Total NPK (kg/alq)	207.00	369.00	203.00	211.00	245.00	258.00
X_6 = Labor (Cr$/alq)	118.00	104.50	128.00	105.00	117.00	211.00
X_7 = Seed & Defensives (Cr$/alq)	211.00	268.00	183.00	201.00	224.00	217.00
X_8 = Machinery (Cr$/alq)	245.00	242.50	247.00	245.00	219.00	347.50
X_9 = Labor & Machinery (Cr$/alq)	412.00	384.00	406.00	403.00	377.00	620.00
X_{10} = Operating Expenses (Cr$/alq)	672.00	693.00	666.00	646.00	646.00	898.00
X_{11} = Management Index (0-4000)	1690.00	1870.00	1610.00	1610.00	1870.00	1560.00
X_{12} = Crop/Cultivated Area (0.00)	0.28	0.31	0.30	0.345	0.30	0.22
X_{13} = Crop Land (alq)	12.70	17.10	10.50	15.00	18.80	7.60
Farm Size in Cultivated Area	40.40	52.90	35.10	40.65	39.20	36.10
No. of Observations	82	30	52	43	29	10

[a]Nitrogen ≥ 50kg/alq or Phosphate ≥ 100 kg/alq or Potash ≥ 100 kg/alq.

[b]One alqueire is equal to 2.2 hectares or 5.98 acres

Table 42 Geometric Values of Cotton Production Variables by Total, Level of Fertilizer Use and Location

Variables	Sample B High	Sample B Low
Y_1 = Cotton Yield (kg/alq)	207.00	171.00
X_1 = Lime (tons/alq)	4.10	4.06
X_2 = Nitrogen (kg/alq)	47.50	25.00
X_3 = Phosphate (kg/alq)	193.00	100.00
X_4 = Potash (kg/alq)	161.00	90.00
X_5 = Total NPK (kg/alq)	412.00	219.00
X_6 = Labor (Cr$/alq)	108.00	143.00
X_7 = Seed & Defensives (Cr$/alq)	222.00	187.00
X_8 = Machinery (Cr$/alq)	250.00	242.00
X_9 = Labor & Machinery (Cr$/alq)	408.00	428.00
X_{10} = Operating Expenses (Cr$/alq)		
X_{11} = Management Index II (0-4000)	1690.00	1690.00
X_{12} = Crop/Cultivated Area (0.00)	0.335	0.25
X_{13} = Crop Land (alq)	16.40	10.00
Farm Size in Cultivated Area	49.30	40.30
No. of Observations	35	35

Table 43 Arithmetic Mean Values of Soybean Production Variables by Total, Level of Fertilizer Use and Location

Variables[b]	Total Sample	Sample A High[a] NPK	Sample A Low NPK	Guaira	Jard-Sales & Others
Y_4 = Soybean Yield (60 kg/alq)	64.22	61.65	66.13	67.25	52.12
X_1 = Lime (60 tons/alq)	3.11	2.32	3.69	3.65	0.94
X_2 = Nitrogen (kg/alq)	20.65	28.88	14.56	23.03	11.12
X_3 = Phosphate (kg/alq)	111.67	202.06	44.87	122.44	68.62
X_4 = Potash (kg/alq)	80.00	132.53	41.17	85.62	57.50
X_5 = Total NPK (kg/alq)	212.32	363.47	100.61	231.09	137.25
X_6 = Labor (Cr$/alq)	143.53	115.42	164.30	126.09	213.26
X_7 = Seed and Defensives (Cr$/alq)	138.88	106.00	163.17	140.03	134.25
X_8 = Machinery (Cr$/alq)	314.32	315.06	313.77	321.28	286.49
X_9 = Labor & Machinery (Cr$/alq)	457.85	430.48	478.07	447.37	499.75
X_{10} = Operating Expenses (Cr$/alq)	596.72	536.48	641.24	587.40	633.99
X_{11} = Management Index (0-4000)	1873.30	1744.82	1968.26	1852.19	1957.75
X_{12} = Crop/Cultivated Area (0.00)	0.333	0.378	0.299	0.373	0.172
X_{13} = Crop Land (alq)	31.84	23.79	37.78	35.45	17.38
Farm Size in Cultivated Area (alq)	111.59	80.68	134.43	111.16	113.31
Number of Observations	40	17	23	32	8

[a] Phosphate ≥ 100 kg/alq or Potash ≥ 100 kg/alq.

[b] One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 49 . Arithmetic Mean Values of Soybean Production Variables by Total, Level of Fertilizer Use and Location

Variables	Sample B All	Sample B Other
Y_4 = Soybean Yield (60 kg/alq)	53.48	82.13
X_1 = Lime (60 tons/alq)	40.44	15.47
X_2 = Nitrogen (kg/alq)	22.96	6.00
X_3 = Phosphate (kg/alq)	90.56	59.87
X_4 = Potash (kg/alq)	52.80	52.73
X_5 = Total NPK (Kg/alq)	166.32	118.60
X_6 = Labor (Cr$/alq)	137.56	153.48
X_7 = Seed and Defensives (Cr$/alq)	87.08	225.20
X_8 = Machinery (Cr$/alq)	316.37	310.90
X9 = Labor & Machinery (Cr$/alq)	453.92	464.38
X_{10} = Operating Expenses (Cr$/alq)		
X_{11} = Management Index II (0-4000)	756.32	2068.27
X_{12} = Crop/Cultivated Area (0.00)	0.36	0.28
X_{13} = Crop Land (alq)	29.72	35.37
Farm Size in Cultivate d Ar	98.22	133.87
No. of Observations	25	15

Table 44 Geometric Values of Soybean Production Variables by Total, Level of Fertilizer Use and Location

Variable[b]	Total Sample	High[a]	Low	Guiara	Jard-Sales & Others
Y_4 = Soybean Yield (60 kg/alq)	53.00	58.00	49.00	54.00	50.00
X_1 = Lime (tons/alq)	5.70	8.01	4.44	7.10	2.36
X_2 = Nitrogen (kg/alq)	3.13	4.57	2.37	3.36	2.34
X_3 = Phosphate (kg/alq)	40.00	111.00	19.00	49.00	17.00
X_4 = Potash (kg/alq)	19.00	37.00	12.00	23.00	8.33
X_5 = Total NPK (kg/alq)	85.00	245.00	39.00	104.00	37.00
X_6 = Labor (Cr$/alq)	86.00	75.00	95.00	75.00	143.00
X_7 = Seed and Defensives (Cr$/alq)	97.00	84.00	108.00	93.00	115.00
X_8 = Machinery (Cr$/alq)	282.00	299.00	268.00	305.00	199.00
X_9 = Labor & Machinery (Cr$/alq)	412.00	404.00	416.00	412.00	396.00
X_{10} = Operating Expenses (Cr$/alq)	534.00	502.00	556.00	529.00	561.00
X_{11} = Management Index II (0-4000)	1780.00	610.00	910.00	740.00	1890.00
X_{12} = Crop/cultivated Are (0.00)	0.27	0.30	0.25	0.31	0.15
X_{13} = Crop Land (alq)	17.60	15.50	19.50	18.90	13.10
Farm Size in Cultivated A (alq)	65.20	51.30	78.10	60.20	88.90
No. of Observations	40	17	23	32	8

[a]Nitrogen ≥ 50 kg/alq or Phosphate ≥ 100 kg/alq or Potash ≥ 100 kg/alq

[b]One alqueire is equal to 2.42 hectares or 5.98 acres.

Table 44 Geometric Values of Soybean Production Variables by Total, Level of Fertilizer Use and Location

Variables	Sample B All	Sample B Other
Y_4 = Soybean Yield (60 kg/alq)	50.00	58.00
X_1 = Lime (tons/alq)	7.10	3.98
X_2 = Nitrogen (kg/alq)	4.39	1.51
X_3 = Phosphate (kg/alq)	83.00	10.00
X_4 = Potash (kg/alq)	47.00	3.04
X_5 = Total NPK (kg/alq)	147.00	28.00
X_6 = Labor (Cr$/alq)	76.00	105.00
X_7 = Seed and Defensives (Cr$/alq)	79.00	147.00
X_8 = Machinery (Cr$/alq)	305.00	245.00
X_9 = Labor & Machinery (Cr$/alq)	424.00	392.00
X_{10} = Operating Expenses (Cr$/alq)		
X_{11} = Management Index II (0-4000)	1660.00	1965.00
X_{12} = Crop/cultivated Area (0.00)	0.33	0.22
X_{13} = Crop Land (alq)	20.10	14.10
Farm Size in Cultivated Area (alq)	65.20	65.20
No. of Observations	25	15

APPENDIX G

RESULTS OF ANALYSIS

Table 45

Regional All Crop Production Functions[a/]

Variables	Regression Coefficients[b] Model III	Model IV	Model V	Model VI
Constant	2.406	2.593	2.907	2.313
X_1 = Lime (tons/alq)	0.012* (0.016)	0.015* (0.018)	0.012* (0.016)	0.011* (0.016)
X_2 = Nitrogen (kg/alq)				
X_3 = Phosphate (kg/alq)				
X_4 = Potash (kg/alq)				
X_5 = Total Fertilizer (kg/alq)	0.006 (0.021)	0.028* (0.024)	0.012 (0.021)	0.004 (0.021)
X_6 = Labor (Cr$/alq)	0.038* (0.044)			
X_7 = Seed and Def. (Cr$/alq)	0.203** (0.029)		0.203** (0.029)	(0.028)
X_8 = Machinery (Cr$/alq)	0.046** (0.025)			
X_9 = Labor & Machinery (Cr$/alq)			0.117** (0.035)	0.087** (0.035)
X_{10} = Operating Expenses (Cr$/alq)		0.069* (0.058)		
X_{11} = Management Index II	0.114* (0.084)	0.130* (0.097)		0.117* (0.080)
X_{12} = Crop Land/ Cultivated Land	-0.127* (0.116)	-0.174* (0.135)		
X_{13} = Crop Land (alq)	0.002 (0.041)	0.075* (0.046)	-0.016 (0.027)	
Standard Error of Estimate	0.357	0.414	0.363	0.361
Simple R^2	0.415	0.201	0.382	0.389
F - Ratio	12.578**	6.047**	17.906**	18.481**

* Significant at 0.50 level ** Significant at 0.10 level

a 151 Observations

b Numbers in parentheses are standard errors of regression coefficients.

Table 45 Regional All Crop Production Functions[a]

Variables	Regression Coefficients[b] Model VII	Model VIII	Model IX	Model X
Constant	2.666	2.934	2.474	2.272
X_1 = Lime (tons/alq)	0.020* (0.018)	0.017* (0.016)	0.014* (0.015)	
X_2 = Nitrogen (kg/alq)	-0.066** (0.030)	-0.067** (0.026)	-0.063** (0.025)	-0.063** (0.025)
X_3 = Phosphate (kg/alq)	0.032* (0.025)	0.021* (0.022)	0.017* (0.022)	0.019* (0.022)
X_4 = Potash (kg/alq)	0.045** (0.026)	0.036** (0.023)	0.030* (0.023)	0.032* (0.023)
X_5 = Total Fertilizer (kg/alq)				
X_6 = Labor (Cr$/alq)				
X_7 = Seed and Def. (Cr$/alq)		0.197** (0.029)	0.186** (0.028)	0.198** (0.029)
X_8 = Machinery (Cr$/alq)				
X_9 = Labor & Machinery (Cr$/alq)		0.126** (0.034)	0.096** (0.035)	0.110** (0.036)
X_{10} = Operating Expenses (Cr$/alq)	0.096* (0.058)			
X_{11} = Management Index II	0.113* (0.095)		0.092* (0.079)	0.119* (0.082)
X_{12} = Crop Land/ Cultivated Land	-0.119* (0.134)			
X_{13} = Crop Land (alq)	0.046* (0.047)	-0.027* (0.027)		-0.033* (0.028)
Standard Error of Estimate	0.241	0.417	0.418	0.421
Simple R^2	0.406	0.355	0.354	0.354
F - Ratio	5.650**	14.598**	14.683**	14.827**

* Significant at 0.50 level ** Significant at 0.10 level

a 151 Observations

b Numbers in parentheses are standard errors of regression coefficients.

TABLE 46.--Regional all crop quadratic production functions[a]

Variables	Regression Coefficients[b] Model XI	Model XII
Constant	83.967	87.684
X_1 - Lime	-0.002	
	(0.004)	
X_5 - Total NPK	0.050*	
	(0.044)	
X_{14} - $(NPK)^2$	-0.00002*	
	(0.00002)	
X_{16} - Lime (NPK)		0.00008
		0.0002)
X_{17} -(Lime $(NPK))^2$		0.0000
		0.0000)
X_7 - Seed & Defensives	0.482**	0.496**
	(0.046)	0.044)
X_9 - Labor & Machinery	-0.0002*	0.0002*
	(0.0001)	0.0001)
X_{11} - Mgt. Index II	0.002	0.004*
	(0.004)	0.004)
X_{13} - Crop Land	0.005*	0.005*
	(0.006)	0.006)
Standard Error of Estimate	48.570	8.617
Simple R^2	0.507	0.503
F-Ratio	21.010**	4.252**

*Significant at 0.50 level.

**Significant at 0.10 level.

[a]151 observations

[b]Numbers in parentheses are standard errors of regression coefficients.

TABLE[46].--Regional all crop quadratic production functions[a]

Variables	Regression Coefficients[b] Model XIII	Variables	Model XIV
Constant	108.297	Constant	87.769
X_1 - Lime	-0.004 (0.013)	X_{17} - Lime & Nitrogen	-0.0002 (0.0007)
X_2 - Nitrogen	-1.140** (0.656)	X_{18} - Lime & Phosp.	-0.0003 (0.0006)
X_3 - Phosphate	0.200** (0.122)	X_{19} - Lime & Potash	0.0012 (0.0026)
X_4 - Potash	0.521** (0.226)	X_9 - Labor & Mach.	-0.0001* (0.0001)
X_{20} - Nitrogen Squared	0.007* (0.005)	X_7 - Seed & Defens.	0.494** (0.044)
X_{21} - Phosphate Squared	-0.00004* (0.00005)	X_{11} - Management	0.004* (0.004)
X_{22} - Potash Squared	-0.0005* (0.0009)	X_3 - Crop Land	0.004* (0.007)
X_{23} - Interaction of Nitrogen and Phosphate	0.002* (0.003)		
X_{24} - Interaction of Nitrogen and Potash	0.0001 (0.0003)		
X_{25} - Interaction of Phosphate & Potash	-0.001* (0.001)		
X_{10} - Operating Expenses	0.0001* (0.0001)		
Standard Error of Estimate	63.758	Standard Error of Estimate	48.791
Simple R^2	0.180	Simple R^2	0.502
F-Ratio	2.528**	F-Ratio	20.636*

*Significant at 0.50 level.

**Significant at 0.10 level.

[a]151 observations

[b]Numbers in parentheses are standard errors of regression coee coefficients.

Table 47 Guaira All Crop Production Functions[a]

Variables	Regression Coefficients[b] Model III	Model IV	Model V	Model VI
Constant	2.506	2.436	2.496	2.459
X_1 = Lime (tons/alq)	-0.010 (0.021)	-0.011 (0.022)	-0.006 (0.022)	
X_2 = Nitrogen (kg/alq)			-0.035* (0.038)	-0.036* (0.037)
X_3 = Phosphate (kg/alq)			-0.001 (0.036)	-0.001 (0.036)
X_4 = Potash (kg/alq)			0.051* (0.036)	0.052* (0.036)
X_5 = Total Fertilizer (kg/alq)	0.022* (0.027)	0.013 (0.028)		
X_6 = Labor (Cr$/alq)	0.037* (0.060)			
X_7 = Seed and Def. (Cr$/alq)	0.298** (0.056)	0.335** (0.059)	0.337** (0.060)	0.339** (0.059)
X_8 = Machinery (Cr$/alq)	0.069** (0.038)			
X_9 = Labor & Machinery (Cr$/alq)		0.104* (0.064)	0.110* (0.064)	0.111* (0.063)
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II	-0.006 (0.098)	-0.004 (0.105)	-0.016 (0.106)	-0.010 (0.102)
X_{12} = Crop Land/ Cultivated Land	-0.363** (0.189)			
X_{13} = Crop Land (alq)	0.040* (0.054)	0.006 (0.046)	-0.006 (0.046)	-0.012 (0.042)
Standard Error of Estimate	0.281	0.303	0.301	0.298
Simple R^2	0.699	0.638	0.656	0.655
F - Ratio	14.792**	15.565**	12.146**	14.118**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 60 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 48 Jard.-Sales All Crop Production Functions[a]

Variables	Regression Coefficients[b] Model III	Model IV	Model V	Model VI
Constant	2.178	1.334	1.585	1.414
X_1 = Lime (ton/alq)	0.026* (0.027)	0.023* (0.029)	0.028* (0.031)	
X_2 = Nitrogen (kg/alq)			-0.044* (0.043)	-0.032* (0.041)
X_3 = Phosphate (kg/alq)			0.016 (0.035)	0.024* (0.034)
X_4 = Potash (kg/alq)			0.016 (0.038)	0.005 (0.037)
X_5 = Total Fertilizer (kg/alq)	-0.005 (0.033)	-0.001 (0.035)		
X_6 = Labor (Cr$/alq)	0.072* (0.063)			
X_7 = Seed and Def. (Cr$/alq)	0.117** (0.043)	0.137** (0.045)	0.140** (0.046)	0.138** (0.046)
X_8 = Machinery (Cr$/alq)	0.152** (0.047)			
X_9 = Labor & Machinery (Cr$/alq)		0.164** (0.056)	0.169** (0.057)	0.175** (0.057)
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II	0.074 (0.160)	0.206* (0.163)	0.166* (0.165)	0.178* (0.164)
X_{12} = Crop Land/ Cultivated Land	0.056 (0.181)			
X_{13} = Crop Land (alq)	-0.009 (0.070)	-0.032* (0.044)	-0.036* (0.045)	-0.030* (0.044)
Standard Error of Estimate	0.342	0.362	0.366	0.366
Simple R^2	0.478	0.380	0.400	0.390
F - Ratio	5.613**	6.372**	4.088**	4.562**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 58 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 49 Other Areas All Crop Production Functions[a]

Variables	Regression Coefficients[b] Model III	Model IV	Model V	Model VI
Constant	4.864	4.922	5.180	4.892
X_1 = Lime (tons/alq)	0.035* (0.037)	0.028* (0.034)	0.027* (0.037)	
X_2 = Nitrogen (kg/alq)			-0.058* (0.064)	-0.054* (0.063)
X_3 = Phosphate (kg/alq)			0.023 (0.066)	0.037 (0.062)
X_4 = Potash (kg/alq)			0.010 (0.065)	
X_5 = Total Fertilizer (kg/alq)	-0.006 (0.052)	-0.001 (0.050)		-0.005 (0.061)
X_6 = Labor (Cr$/alq)	-0.001 (0.112)			
X_7 = Seed and Def. (Cr$/alq)	0.134** (0.068)	0.128** (0.065)	0.120* (0.069)	0.134* (0.065)
X_8 = Machinery (Cr$/alq)	-0.042* (0.048)			
X_9 = Labor & Machinery (Cr$/alq)		-0.057* (0.080)	-0.044 (0.085)	-0.050* (0.084)
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index I	0.035 (0.234)	0.030 (0.222)	-0.017 (0.238)	0.032 (0.226)
X_{12} = Crop Land/ Cultivated Land	0.192 (0.307)			
X_{13} = Crop Land (alq)	-0.112* (0.102)	-0.082* (0.067)	-0.072* (0.071)	-0.084* (0.068)
Standard Error of Estima	0.362	0.354	0.362	0.358
Simple R^2	0.243	0.212	0.241	0.224
F - Ratio	0.963*	1.166*	0.953*	1.033*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 33 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 50 Regional Corn Production Functions[a]

Variables	Regression Coefficients[b] Model III	Model IV	Variables	Reg. Coeff.[b] Model V
Constant	3.295	3.284	Constant	97.479
K_1 = Lime (tons/alq)	-0.032** (0.019)	-0.023* (0.020)	X_1 = Lime (tons/alq)	
K_2 = Nitrogen (kg/alq)		-0.040* (0.025)	X_2 = Nitrogen (kg/alq)	-0.485** (0.246)
K_3 = Phosphate (kg/alq)		0.019* (0.024)	X_3 = Phosphate (kg/alq)	0.012 (0.163)
K_4 = Potash (kg/alq		0.019* (0.027)	X_4 = Potash (kg/alq)	0.342* (0.178)
K_5 = Total Fertiliser (kg/alq)	0.002 (0.023)		X_{20} = Nitrogen Squared	0.002** (0.001)
K_6 = Labor (Cr$/alq)	-0.035 (0.051)		X_{21} = Phosphate Squared	0.0004 (0.0008)
K_7 = Seed and def. (Cr$/al	0.134** (0.065)		X_{22} = Potash Squared	-0.0005* (0.0003)
K_8 = Machine (Cr$/al	0.037* (0.036)		X_{23} = Nitrogen & Phosphate	0.001* (0.001)
X_9 = Labor & Machinery (Cr$/alq)			X_{24} = Nitrogen & Potash	0.002* (0.003)
X_{10} = Operating Expenses (Cr$/alq)		0.182** (0.059)	X_{25} = Phosphate & Potash	-0.001* (0.001)
X_{11} = Management Index II	0.061 (0.092)		X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land	-0.215** (0.070)		X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	0.032* (0.040)	0.045* (0.029)	X_{10} = Total Expenses	-0.0004** (0.0002)
Standard Error of Estimate	0.394	0.409		40.678
Simple R^2	0.188	0.110		0.158
F - Ratio	4.103**	2.960**		2.660**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 151 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 51 Subregion Corn Production Functions

Variables	Regression Coefficients[c] Guaira[a] Model I	Guaira[a] Model II	Jard-Seles[b] Model I	Jard-Seles[b] Model II
Constant	2.338	2.311	1.106	1.248
X_1 = Lime (tons/alq)	-0.062** (0.027)	-0.056** (0.027)	0.010 (0.031)	0.020 (0.034)
X_2 = Nitrogen (kg/alq)		-0.043* (0.039)		-0.026* (0.039)
X_3 = Phosphate (kg/alq)		0.033* (0.045)		-0.000 (0.028)
X_4 = Potash (kg/alq)		0.024 (0.048)		0.015 (0.040)
X_5 = Total Fertilizer (kg/alq)	0.035* (0.037)			
X_6 = Labor (Cr$/alq)			0.010 (0.030)	
X_7 = Seed and Def. (Cr$/alq)	0.108* (0.111)	0.109* (0.110)	0.138* (0.087)	0.131* (0.090)
X_8 = Machinery (Cr$/alq)				
X_9 = Labor & Machinery (Cr$/alq)	0.11[illegible] (0.09[illegible]	0.106* (0.095)	0.286** (0.080)	0.277** (0.083)
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II	0.101* (0.123)	0.130* (0.123)	0.145* (0.157)	0.144* (0.159)
X_{12} = Crop Land/ Cultivated Land				
X_{13} = Crop Land (alq)	0.087* (0.055)	0.073* (0.055)	0.057* (0.046)	0.059* (0.048)
Standard Error of Estimate	0.387	0.385	0.340	0.346
Simple R^2	0.249	0.286	0.326	0.331
F - Ratio	2.924**	2.560**	4.102**	3.032**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 60 Observations [b] 58 observations.

[c] Numbers in parentheses are standard errors of regression coefficients.

Table 51 Subregion Corn Production Functions

Variables	Regression Coefficients[b] Other Areas[a] Model I	Model II
Constant	5.748	5.727
X_1 = Lime (tons/alq)	-0.031 (0.063)	-0.042 (0.070)
X_2 = Nitrogen (kg/alq)		-0.042 (0.077)
X_3 = Phosphate (kg/alq)		0.017 (0.109)
X_4 = Potash (kg/alq)		0.026 (0.123)
X_5 = Total Fertilizer (kg/alq)	-0.056 (0.082)	
X_6 = Labor (Cr$/alq)		
X_7 = Seed and Def. (Cr$/alq)	0.270* (0.188)	0.274* (0.195)
X_8 = Machinery (Cr$/alq)		
X_9 = Labor & Machinery (Cr$/alq)	0.026 (0.159)	0.028 (0.173)
X_{10} = Operating Expenses (Cr$/alq)		
X_{11} = Management Index II	-0.241* (0.301)	-0.260 (0.324)
X_{12} = Crop Land/ Cultivated Land		
X_{13} = Crop Land (alq)	-0.054 (0.084)	-0.047 (0.091)
Standard Error of Estimate	0.495	0.514
Simple R^2	0.124	0.130
F - Ratio	0.615	0.448

* Significant at 0.50 level ** Significant at 0.10 level

[a] 33 Observations

[b] Numbers in parentheses are standard errors of regression coefficients

Table 52 Sample A - High Group Corn Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	0.057	0.984	Constant	88.238
X_1 = Lime (tons/alq)	-0.019 (0.032)	-0.004 (0.034)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.055* (0.040)	X_2 = Nitrogen (kg/alq)	-0.274 (0.578)
X_3 = Phosphate (kg/alq)		0.006 (0.036)	X_3 = Phosphate (kg/alq)	0.133 (0.410)
X_4 = Potash (kg/alq)		0.041* (0.032)	X_4 = Potash (kg/alq)	0.353* (0.323)
X_5 = Total Fertilizer (kg/alq)	0.242** (0.101)		X_{20} = Nitrogen Squared	0.001 (0.002)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	-0.0001 (0.0016)
X_7 = Seed and def. (Cr$/alq)	0.152* (0.101)	0.160* (0.104)	X_{22} = Potash Squared	0.0005* (0.0007)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.001 (0.002)
X_9 = Labor & Machinery (Cr$/alq)	0.158** (0.087)	0.194** (0.089)	X_{24} = Nitrogen & Potash	0.0001 (0.0028)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	-0.0007* (0.0010)
X_{11} = Management Index II	0.226* (0.160)	0.248* (0.168)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	0.030 (0.048)	0.033 (0.051)	X_{10} = Total Expenses	0.007 (0.018)
Standard Error of Estimate	0.359	0.366		37.858
Simple R^2	0.370	0.375		0.333
F - Ratio	3.917**	2.854**		1.800**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 47 Observations
[b] Numbers in parentheses are andard errors of regression coefficients.

Table 53 Sample A, Low Group, Corn Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	R[illegible] Model III
Constant	2.843	2.910	Constant	102.104
X_1 = Lime (tons/alq)	-0.029* (0.024)	-0.029* (0.025)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.047* (0.053)	X_2 = Nitrogen (kg/alq)	-1.360* (1.362)
X_3 = Phosphate (kg/alq)		0.016 (0.042)	X_3 = Phosphate (kg/alq)	-0.112 (0.525)
X_4 = Potash (kg/alq)		0.012 (0.052)	X_4 = Potash (kg/alq)	0.010 (0.762)
X_5 = Total Fertilizer (kg/alq)	-0.006 (0.027)		X_{20} = Nitrogen Squared	0.006* (0.006)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.002 (0.004)
X_7 = Seed and def. (Cr$/alq)	0.125* (0.085)	0.124* (0.086)	X_{22} = Potash Squared	-0.001* (0.001)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-0.002 (0.012)
X_9 = Labor & Machinery (Cr$/alq)	0.099* (0.079)	0.099* (0.080)	X_{24} = Nitrogen & Potash	0.023* (0.017)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	-0.001 (0.007)
X_{11} = Management Index II	0.095* (0.118)	0.085* (0.118)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	0.014 (0.043)	0.014 (0.044)	X_{10} = Total Expenses	0.002 (0.005)
Standard Error of Estimate	0.422	0.424		42.621
Simple R^2	0.076	0.084		0.084
F - Ratio	1.334*	1.092*		0.847

* Significant at 0.50 level

[a] 104 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 54 Sample B, All Group, Corn Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II
Constant	0.974	1.125
X_1 = Lime (tons/alq)	-0.021* (0.026)	-0.021* (0.027)
X_2 = Nitrogen (kg/alq)		-0.022 (0.064)
X_3 = Phosphate (kg/alq)		0.099* (0.106)
X_4 = Potash (kg/alq)		0.180** (0.111)
X_5 = Total Fertilizer (kg/alq)	0.264** (0.099)	
X_6 = Labor (Cr$/alq)		
X_7 = Seed and def. (Cr$/alq)	0.224** (0.087)	0.226** (0.088)
X_8 = Machinery (Cr$/alq)		
X_9 = Labor & Machinery (Cr$/alq)	0.109* (0.080)	0.087* (0.084)
X_{10} = Operating Expenses (Cr$/alq)		
X_{11} = Management Index II	0.113* (0.114)	0.150* (0.120)
X_{12} = Crop Land/Cultivated Land		
X_{13} = Crop Land (alq)	0.004 (0.044)	-0.003 (0.044)
Standard Error of Estimate	0.413	0.415
Simple R^2	0.226	0.236
F - Ratio	[illegible]	3.352**

Variables	Reg. Coeff.[b] Model III
Constant	41.216
X_1 = Lime (tons/alq)	-0.025 (0.037)
X_2 = Nitrogen (kg/alq)	-0.614* (0.668)
X_3 = Phosphate (kg/alq)	0.728* (0.508)
X_4 = Potash (kg/alq)	0.481* (0.411)
X_{20} = Nitrogen Squared	0.007* (0.005)
X_{21} = Phosphate Squared	-0.003* (0.003)
X_{22} = Potash Squared	-0.001 (0.003)
X_{23} = Nitrogen & Phosphate	-.0001 (0.0039)
X_{24} = Nitrogen & Potash	-0.003 (0.007)
X_{25} = Phosphate & Potash	0.002 (0.005)
X_7 = Seed & Def.	0.241* (0.158)
X_9 = Labor & Machinery	0.001 (0.004)
X_{10} = Total Expenses	
Standard Error of Estimate	42.615
Simple R^2	0.240
F - Ratio	2.186**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 96 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 55 Sample B, High Groups, Corn Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	1.964	1.759	Constant	190.08
X_1 = Lime (tons/alq)	-0.064** (0.036)	-0.058* (0.037)	X_1 = Lime (tons/alq)	-0.362* (0.498)
X_2 = Nitrogen (kg/alq)		-0.071* (0.079)	X_2 = Nitrogen (kg/alq)	-3.745** (2.088)
X_3 = Phosphate (kg/alq)		0.068 (0.156)	X_3 = Phosphate (kg/alq)	-0.648 (1.513)
X_4 = Potash (kg/alq)		0.173* (0.126)	X_4 = Potash (kg/alq)	0.853* (0.785)
X_5 = Total Fertilizer (kg/alq)	0.186* (0.196)		X_{20} = Nitrogen Squared	0.003 (0.008)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.003 (0.007)
X_7 = Seed and def. (Cr$/alq)	0.152* (0.127)	0.178* (0.130)	X_{22} = Potash Squared	-0.002 (0.004)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.008* (0.008)
X_9 = Labor & Machinery (Cr$/alq)	-0.078* (0.112)	-0.116* (0.115)	X_{24} = Nitrogen & Potash	0.017* (0.015)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.005 (0.008)
X_{11} = Management Index II	0.261* (0.206)	0.345* (0.220)	X_7 = Seed & Def.	0.334* (0.353)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	-0.001 (0.005)
X_{13} = Crop Land (alq)	-0.028 (0.062)	-0.050* (0.064)	X_{10} = Total Expenses	
Standard Error of Estimate	0.370	0.369		45.988
Simple R^2	0.173	0.224		0.275
F - Ratio	1.255*	1.229*		0.950

* Significant at 0.50 level ** Significant at 0.10 level

[a] 43 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 56 Sample B, Low Group, Corn Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	1.725	1.850	Constant	173.346
X_1 = Lime (tons/alq)	-0.015 (0.041)	-0.011 (0.042)	X_1 = Lime (tons/alq)	-0.054* (0.038)
X_2 = Nitrogen (kg/alq)		0.059 (0.110)	X_2 = Nitrogen (kg/alq)	-0.103 (1.817)
X_3 = Phosphate (kg/alq)		-0.032 (0.201)	X_3 = Phosphate (kg/alq)	-1.549* (1.553)
X_4 = Potash (kg/alq)		0.011 (0.236)	X_4 = Potash (kg/alq)	-2.161* (2.212)
X_5 = Total Fertilizer (kg/alq)	0.040 (0.216)		X_{20} = Nitrogen Squared	-0.003 (0.013)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	-0.017* (0.009)
X_7 = Seed and def. (Cr$/alq)	0.227** (0.123)	0.232** (0.128)	X_{22} = Potash Squared	-0.014 (0.032)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.022 (0.045)
X_9 = Labor & Machinery (Cr$/alq)	0.179* (0.127)	0.180* (0.138)	X_{24} = Nitrogen & Potash	-0.021 (0.052)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.064** (0.036)
X_{11} = Management Index II	0.104* (0.147)	0.099 (0.154)	X_7 = Seed & Def.	0.264** (0.169)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	0.037* (0.025)
X_{13} = Crop Land (alq)	-0.008 (0.064)	-0.009 (0.066)	X_{10} = Total Expenses	
Standard Error of Estimate	0.442	0.450		38.128
Simple R^2	0.162	0.166		0.278
F - Ratio	1.467*	1.098*		1.284*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 53 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 57 Sample B, Other Group, Corn Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	3.040	2.981	Constant	104.112
X_1 = Lime (tons/alq)	-0.036* (0.034)	-0.032* (0.036)	X_1 = Lime (tons/alq)	-0.011* (0.006)
X_2 = Nitrogen (kg/alq)		-0.050* (0.031)	X_2 = Nitrogen (kg/alq)	-5.409* (3.043)
X_3 = Phosphate (kg/alq)		-0.012 (0.343)	X_3 = Phosphate (kg/alq)	54.834** (24.412)
X_4 = Potash (kg/alq)		0.011 (0.374)	X_4 = Potash (kg/alq)	-54.087** (24.881)
X_5 = Total Fertilizer (kg/alq)	-0.054* (0.038)		X_{20} = Nitrogen Squared	0.001* (0.001)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	
X_7 = Seed and def. (Cr$/alq)	0.095* (0.134)	0.094* (0.139)	X_{22} = Potash Squared	-4.854* (3.087)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-7.201** (3.503)
X_9 = Labor & Machinery (Cr$/alq)	0.017 (0.104)	0.014 (0.115)	X_{24} = Nitrogen & Potash	12.407** (6.540)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	
X_{11} = Management Index II	0.156* (0.172)	0.161* (0.176)	X_7 = Seed & Def.	0.098 (0.468)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	-0.006 (0.018)
X_{13} = Crop Land (alq)	0.022 (0.048)	0.021 (0.050)	X_{10} = Total Expenses	
Standard Error of Estimate	0.361	0.368		31.649
Simple R^2	0.162	0.183		0.326
F - Ratio	1.063*	0.867		1.405*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 40 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 58 Regional Rice Production Functions[a]

Variables	Regression Coefficients[b] Model III	Model IV	Variables	Reg. Coeff.[b] Model V
Constant	1.444	2.682	Constant	75.174
X_1 = Lime (tons/alq)	0.053** (0.032)	0.045* (0.033)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.060* (0.063)	X_2 = Nitrogen (kg/alq)	-0.219* (0.326)
X_3 = Phosphate (kg/alq)		-0.063** (0.036)	X_3 = Phosphate (kg/alq)	-0.083* (0.056)
X_4 = Potash (kg/alq)		0.022 (0.060)	X_4 = Potash (kg/alq)	-0.457 (0.263)
X_5 = Total Fertilizer (kg/alq)	-0.010 (0.034)		X_{20} = Nitrogen Squared	
X_6 = Labor (Cr$/alq)	0.017 (0.076)		X_{21} = Phosphate Squared	
X_7 = Seed and def. (Cr$/alq)	0.085** (0.049)		X_{22} = Potash Squared	-0.004* (0.005)
X_8 = Machinery (Cr$/alq)	0.180** (0.068)		X_{23} = Nitrogen & Phosphate	-0.005* (0.006)
X_9 = Labor & Machinery (Cr$/alq)			X_{24} = Nitrogen & Potash	0.012* (0.009)
X_{10} = Operating Expenses (Cr$/alq)		0.263** (0.100)	X_{25} = Phosphate & Potash	0.005* (0.003)
X_{11} = Management Index II	0.276* (0.181)		X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land	-0.038** (0.010)	-0.021 (0.054)	X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	-0.131** (0.068)		X_{10} = Total Expenses	0.007* (0.003)
Standard Error of Estimate	0.563	0.585		36,831
Simple R^2	0.234	0.157		0.130
F - Ratio	3.862**	3.199**		1.881**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 110 Observations

[b] Numbers in parentheses are standard errors of regression coefficients

Table 59 Subregion Rice Production Functions

Variables	Model I	Model II	Model III	Model IV
Constant	3.620	3.770	-1.838	1.901
X_1 = Lime (tons/alq)	0.052* (0.046)	0.045* (0.048)	0.114* (0.108)	0.132* (0.113)
X_2 = Nitrogen (kg/alq)		-0.087* (0.079)		0.045 (0.121)
X_3 = Phosphate (kg/alq)		-0.102** (0.060)		-0.090* (0.056)
X_4 = Potash (kg/alq)		0.049 (0.083)		-0.023 (0.107)
X_5 = Total Fertilizer (kg/alq)	-0.125** (0.047)		-0.085* (0.055)	
X_6 = Labor (Cr$/alq)				
X_7 = Seed and Def. (Cr$/alq)	-0.003 (0.064)	-0.002 (0.066)	0.260** (0.110)	0.262** (0.111)
X_8 = Machinery (Cr$/alq)				
X_9 = Labor & Machinery (Cr$/alq)	0.029 (0.239)	0.045 (0.246)	0.331** (0.171)	0.317** (0.173)
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II	0.078 (0.305)	0.026 (0.318)	0.454** (0.290)	0.478** (0.296)
X_{12} = Crop Land/ Cultivated Land				
X_{13} = Crop Land (alq)	0.015 (0.125)	0.120* (0.128)	-0.033 (0.091)	-0.060 (0.094
Standard Error of Estimat	0.511	0.524	0.573	0.578
Simple R^2	0.245	0.259	0.308	0.331
F - Ratio	1.619*	1.223*	2.968**	2.354

* Significant at 0.50 level ** Significant at 0.10 level

a 37 Observations b 47 observations

c [illegible] are standard errors of regression coefficients.

Table 59 Subregional Rice Production Functions

Variables	Regression Coefficients[b] Other Areas[a] Model I	Model II
Constant	0.406	0.962
X_1 = Lime (tons/alq)	0.039 (0.064)	0.050* (0.065)
X_2 = Nitrogen (kg/alq)		-0.326* (0.209)
X_3 = Phosphate (kg/alq)		-0.076* (0.105)
X_4 = Potash (kg/alq)		0.241* (0.191)
X_5 = Total Fertilizer (kg/alq)	-0.073 (0.110)	
X_6 = Labor (Cr$/alq)		
X_7 = Seed and Def. (Cr$/alq)	0.021 (0.109	0.061 (0.111)
X_8 = Machinery (Cr$/alq)		
X_9 = Labor & Machinery (Cr$/alq)	0.193* (0.236)	0.144 (0.238)
X_{10} = Operating Expenses (Cr$/alq)		
X_{11} = Management Index II	0.451 (0.615)	0.428 (0.627)
X_{12} = Crop Land/ Cultivated Land		
X_{13} = Crop Land (alq)	-0.192* (0.181)	-0.247* (0.184)
Standard of Estimate	0.641	0.636
Simple R^2	0.321	0.401
F - Ratio	1.500*	1.421*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 26 Observations

[b] Numbers in parentheses are standard errors of regression coefficients

Table 59 Subregional Rice Production Functions

Variables	Regression Coefficients[b] Other Areas[a] Model I	Model II
Constant	0.406	0.962
X_1 = Lime (tons/alq	0.039 (0.064)	0.050* (0.065)
X_2 = Nitrogen (kg/alq)		-0.326* (0.209)
X_3 = Phosphate (kg/alq)		-0.076* (0.105)
X_4 = Potash (kg/alq)		0.241* (0.191)
X_5 = Total Fertilizer (kg/alq)	-0.073 (0.110)	
X_6 = Labor (Cr$/alq)		
X_7 = Seed and Def. (Cr$/alq)	0.021 (0.109)	0.061 (0.111)
X_8 = Machinery (Cr$/alq)		
X_9 = Labor & Machinery (Cr$/alq)	0.193* (0.236)	0.144 (0.238)
X_{10} = Operating Expenses (Cr$/alq)		
X_{11} = Management Index II	0.451 (0.615)	0.428 (0.627)
X_{12} = Crop Land/ Cultivated Land		
X_{13} = Crop Land (alq)	-0.192* (0.181)	-0.247* (0.184)
Standard Error of Estimate	0.641	0.636
Simple R^2	0.321	0.401
F - Ratio	1.500*	1.421*

* Significant at 0.90 level ** Significant at 0.10 level

[a] 26 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 60 Sample A, High Group, Rice Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	0.019	-0.446	Constant	191.340
X_1 = Lime (tons/alq)	-0.046 (0.078)	-0.049 (0.082)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.106 (0.162)	X_2 = Nitrogen (kg/alq)	-1.834** (0.932)
X_3 = Phosphate (kg/alq)		-0.106* (0.123)	X_3 = Phosphate (kg/alq)	-0.819** (0.362)
X_4 = Potash (kg/alq)		0.046 (0.126)	X_4 = Potash (kg/alq)	-1.086** (0.499)
X_5 = Total Fertilizer (kg/alq)	-0.235* (0.228)		X_{20} = Nitrogen Squared	-0.008* (0.006)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.001* (0.001)
X_7 = Seed and def. (Cr$/alq)	0.031 (0.090)	0.039 (0.097)	X_{22} = Potash Squared	-0.006* (0.005)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.001 (0.006)
X_9 = Labor & Machinery (Cr$/alq)	0.043 (0.218)	0.039 (0.230)	X_{24} = Nitrogen & Potash	0.027** (0.011)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.006** (0.003)
X_{11} = Management Index II	0.719** (0.402)	0.692* (0.424)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	-0.115* (0.112)	-0.103* (0.117)	X_{10} = Total Expenses	-0.001 (0.009)
Standard Error of Estimate	0.626	0.648		30.510
Simple R^2	0.133	0.138		0.407
F - Ratio	0.689	0.500		1.577*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 34 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 61 Sample A, Low Group, Rice Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	1.354	1.363	Constant	76.709
X_1 = Lime (tons/alq)	0.068** (0.037)	0.076** (0.037)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.081* (0.112)	X_2 = Nitrogen (kg/alq)	1.456 (2.263)
X_3 = Phosphate (kg/alq)		-0.140** (0.051)	X_3 = Phosphate (kg/alq)	-0.886** (0.468)
X_4 = Potash (kg/alq)		0.119* (0.095)	X_4 = Potash (kg/alq)	-1.049* (1.210)
X_5 = Total Fertilizer (kg/alq)	-0.098** (0.041)		X_{20} = Nitrogen Squared	-0.003 (0.056)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.007* (0.006)
X_7 = Seed and def. (Cr$/alq)	0.118* (0.069)	0.130** (0.070)	X_{22} = Potash Squared	0.019* (0.020)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-0.011 (0.026)
X_9 = Labor & Machinery (Cr$/alq)	0.246** (0.118)	0.218** (0.118)	X_{24} = Nitrogen & Potash	-0.022 (0.055)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.003 (0.014)
X_{11} = Management Index II	0.165* (0.207)	0.188* (0.206)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	-0.044 (0.075)	-0.081* (0.077)	X_{10} = Total Expenses	0.008** (0.003)
Standard Error of Estimate	0.549	0.544		38.612
Simple R^2	0.297	0.331		0.201
F - Ratio	4.864**	4.145**		1.638*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 76 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 62 Sample B, High Group, Rice Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	-1.236	-1.107	Constant	75.335
X_1 = Lime (tons/alq)	0.012 (0.052)	0.007 (0.056)	X_1 = Lime (tons/alq)	0.002* (0.002)
X_2 = Nitrogen (kg/alq)		-0.080 (0.125)	X_2 = Nitrogen (kg/alq)	-0.929* (1.272)
X_3 = Phosphate (kg/alq)		0.013 (0.213)	X_3 = Phosphate (kg/alq)	-0.197 (0.401)
X_4 = Potash (kg/alq)		0.018 (0.220)	X_4 = Potash (kg/alq)	-0.243 (0.786)
X_5 = Total Fertiliser (kg/alq)	-0.017 (0.184)		X_{20} = Nitrogen Squared	0.001 (0.006)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.001 (0.002)
X_7 = Seed and def. (Cr$/alq)	-0.00001 (0.0490)	0.003 (0.052)	X_{22} = Potash Squared	-0.006 (0.010)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-0.008 (0.017)
X_9 = Labor & Machinery (Cr$/alq)	0.216* (0.196)	0.221* (0.198)	X_{24} = Nitrogen & Potash	0.025* (0.027)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.004 (0.008)
X_{11} = Management Index II	0.556** (0.285)	0.539* (0.296)	X_7 = Seed & Def.	-0.009 (0.015)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	0.015* (0.011)
X_{13} = Crop Land (alq)	-0.066 (0.104)	-0.074 (0.111)	X_{10} = Total Expenses	
Standard Error of Estimate	0.655	0.665		36.757
Simple R^2	0.159	0.166		0.163
F - Ratio	1.602*	1.216*		0.732

* Significant at 0.50 level ** Significant at 0.10 level

[a] 58 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 63 Sample B, Low Group, Rice Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	1.462	1.384	Constant	103.769
X_1 = Lime (tons/alq)	0.115** (0.056)	0.122** (0.060)	X_1 = Lime (tons/alq)	0.012* (0.015)
X_2 = Nitrogen (kg/alq)		-0.038 (0.079)	X_2 = Nitrogen (kg/alq)	5.949* (5.288)
X_3 = Phosphate (kg/alq)		-0.032 (0.186)	X_3 = Phosphate (kg/alq)	-38.658** (19.434)
X_4 = Potash (kg/alq)		0.062 (0.139)	X_4 = Potash (kg/alq)	-15.734 (16.137)
X_5 = Total Fertilizer (kg/alq)	-0.006 (0.068)		X_{20} = Nitrogen Squared	-0.102* (0.074)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	9.408* (6.080)
X_7 = Seed and def. (Cr$/alq)	0.071* (0.056)	0.067* (0.059)	X_{22} = Potash Squared	0.249* (0.232)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.869* (1.165)
X_9 = Labor & Machinery (Cr$/alq)	0.158* (0.157)	0.150* (0.165)	X_{24} = Nitrogen & Potash	
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	-2.284* (1.722)
X_{11} = Management Index II	0.269* (0.322)	0.286* (0.335)	X_7 = Seed & Def.	0.316* (0.222)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	0.002 (0.006)
X_{13} = Crop Land (alq)	-0.103* (0.104)	-0.099* (0.108)	X_{10} = Total Expenses	
Standard Error of Estimate	0.494	0.510		27.501
Simple R^2	0.306	0.315		0.725
F - Ratio	1.987*	1.434*		5.268**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 34 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 64 Sample B, Other Group, Rice Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	6.621	7.506	Constant	22.218
X_1 = Lime (tons/alq)	0.018 (0.078)	-0.009 (0.105)	X_1 = Lime (tons/alq)	0.190 (0.708)
X_2 = Nitrogen (kg/alq)		-0.312* (0.245)	X_2 = Nitrogen (kg/alq)	-1.741* (2.435)
X_3 = Phosphate (kg/alq)		-0.007 (0.198)	X_3 = Phosphate (kg/alq)	0.159 (0.256)
X_4 = Potash (kg/alq)		0.230* (0.216)	X_4 = Potash (kg/alq)	0.860 (2.496)
X_5 = Total Fertilizer (kg/alq)	0.061 (0.192)		X_{20} = Nitrogen Squared	
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	-0.0004* (0.0005)
X_7 = Seed and def. (Cr$/alq)	0.124* (0.072)	0.149* (0.079)	X_{22} = Potash Squared	
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	
X_9 = Labor & Machinery (Cr$/alq)	0.059 (0.231)	0.092 (0.240)	X_{24} = Nitrogen & Potash	
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	
X_{11} = Management Index II	-0.431* (0.461)	-0.536* (0.500)	X_7 = Seed & Def.	0.356* (0.222)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	0.023 (0.013)
X_{13} = Crop Land (alq)	-0.120* (0.116)	-0.153* (0.120)	X_{10} = Total Expenses	
Standard Error of Estimate	0.460	0.466		30.691
Simple R^2	0.400	0.500		0.409
F - Ratio	1.215*	1.107*		0.987*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 18 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 65 Regional Cotton Production Functions[a]

Variables	Regression Coefficients[b] Model III	Model IV	Variables	Reg. Coeff.[b] Model V
Constant	3.965	4.250	Constant	184.548
X_1 = Lime (tons/alq)	0.027* (0.020)	0.028* (0.020)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.053* (0.041)	X_2 = Nitrogen (kg/alq)	-0.500** (0.218)
X_3 = Phosphate (kg/alq)		0.053* (0.037)	X_3 = Phosphate (kg/alq)	0.141* (0.125)
X_4 = Potash (kg/alq)		0.017 (0.036)	X_4 = Potash (kg/alq)	
X_5 = Total Fertilizer (kg/alq)	0.010 (0.043)		X_{20} = Nitrogen Squared	
X_6 = Labor (Cr$/alq)	-0.014 (0.060)		X_{21} = Phosphate Squared	
X_7 = Seed and def. (Cr$/alq)	0.073* (0.066)		X_{22} = Potash Squared	-0.0006 (0.0011)
X_8 = Machinery (Cr$/alq)	-0.043 (0.084)		X_{23} = Nitrogen & Phosphate	0.002 (0.003)
X_9 = Labor & Machinery (Cr$/alq)			X_{24} = Nitrogen & Potash	0.007* (0.004)
X_{10} = Operating Expenses (Cr$/alq)		0.067 (0.107)	X_{25} = Phosphate & Potash	-0.001 (0.001)
X_{11} = Management Index II	0.145* (0.136)		X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land	0.144** (0.079)		X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	0.036* (0.052)	0.074** (0.036)	X_{10} = Total Expenses	
Standard Error of Estimate	0.383			59.460
Simple R^2	0.177			0.193
F - Ratio	1.960*			3.059**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 82 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 66 Subregional Cotton Production Functions

Other Areas b/

Regression Coefficients a/

Variables	Model I	Model II	Model	Model
Constant	6.874	-10.208		
X_1 = Lime (tons/alq)	0.001 (0.080)	-0.353** (0.010)		
X_2 = Nitrogen (kg/alq)		0.422** (0.022)		
X_3 = Phosphate (kg/alq)		3.006** (0.079)		
X_4 = Potash (kg/alq)		-2.419** (0.067)		
X_5 = Total Fertilizer (kg/alq)	0.145 (0.709)			
X_6 = Labor (Cr$/alq)				
X_7 = Seed and Def. (Cr$/alq)	0.353* (0.447)	0.488** (0.018)		
X_8 = Machinery (Cr$/alq)				
X_9 = Labor & Machinery (Cr$/alq)	0.928** (0.485)	1.437** (0.025)		
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II	-1.638** (0.952)	0.174** (0.065)		
X_{12} = Crop Land/ Cultivated Land				
X_{13} = Crop Land (alq)	0.262* (0.225)	-0.568** (0.026)		
Standard Error of Estimate	0.455	0.020		
Simple R^2	0.756	1.000		
F - Ratio	1.545*	778.328**		

* Significant at 0.50 level ** Significant at 0.10 level

b/ 10 Observations

a/ Numbers in parentheses are standard errors of regression coefficients.

Table 67 Sample A., High Group, Cotton Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	2.238	3.051	Constant	277.314
X_1 = Lime (tons/alq)	0.039* (0.035)	0.044* (0.032)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.014 (0.078)	X_2 = Nitrogen (kg/alq)	-1.157* (1.849)
X_3 = Phosphate (kg/alq)		0.123** (0.065)	X_3 = Phosphate (kg/alq)	-0.913* (0.845)
X_4 = Potash (kg/alq)		0.021 (0.056)	X_4 = Potash (kg/alq)	0.665* (0.600)
X_5 = Total Fertilizer (kg/alq)	0.269* (0.207)		X_{20} = Nitrogen Squared	0.0004 (0.0057)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.002* (0.002)
X_7 = Seed and def. (Cr$/alq)	0.130* (0.104)	0.062 (0.093)	X_{22} = Potash Squared	-0.003* (0.002)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.005* (0.004)
X_9 = Labor & Machinery (Cr$/alq)	-0.190* (0.218)	-0.038 (0.198)	X_{24} = Nitrogen & Potash	0.005* (0.005)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	-0.001 (0.003)
X_{11} = Management Index II	0.250* (0.209)	0.220* (0.189)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	-0.006 (0.080)	-0.032 (0.070)	X_{10} = Total Expenses	0.022 (0.039)
Standard Error of Estimate	0.360	0.310		56.096
Simple R^2	0.304	0.530		0.536
F - Ratio	1.670*	2.954**		2.197**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 30 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 68 Sample A, Low Group, Cotton Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	5.183	5.404	Constant	198.213
X_1 = Lime (tons/alq)	0.023* (0.027)	0.027* (0.028)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.167* (0.120)	X_2 = Nitrogen (kg/alq)	-7.019* (4.428)
X_3 = Phosphate (kg/alq)		0.008 (0.071)	X_3 = Phosphate (kg/alq)	-0.046 (0.236)
X_4 = Potash (kg/alq)		0.094* (0.099)	X_4 = Potash (kg/alq)	1.337* (0.934)
X_5 = Total Fertilizer (kg/alq)	-0.018 (0.049)		X_{20} = Nitrogen Squared	0.080 (0.147)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	-0.0001 (0.0002)
X_7 = Seed and def. (Cr$/alq)	0.030 (0.092	0.034 (0.093)	X_{22} = Potash Squared	-0.001 (0.015)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.017* (0.023)
X_9 = Labor & Machinery (Cr$/alq)	0.018 (0.127	0.018 (0.128)	X_{24} = Nitrogen & Potash	-0.026 (0.089)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.000 (0.000)
X_{11} = Management Index II	-0.079 (0.164)	-0.115* (0.168)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	0.076* (0.058)	0.073* (0.058)	X_{10} = Total Expenses	0.013 (0.025)
Standard Error of Estimate	0.405	0.406		59.598
Simple R^2	0.081	0.121		0.151
F - Ratio	0.663	0.737		0.830

* Significant at 0.50 level ** Significant at 0.10 level

[a] 52 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 69 Sample B, High Group, Cotton Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	3.214	3.990	Constant	178.324
X_1 = Lime (tons/alq)	0.043* (0.029)	0.018 (0.033)	X_1 = Lime (tons/alq)	0.164 (0.271)
X_2 = Nitrogen (kg/alq)		0.161* (0.158)	X_2 = Nitrogen (kg/alq)	-1.673 (5.084)
X_3 = Phosphate (kg/alq)		0.022 (0.303)	X_3 = Phosphate (kg/alq)	1.039* (1.486)
X_4 = Potash (kg/alq)		-0.336* (0.209)	X_4 = Potash (kg/alq)	-0.649 (1.584)
X_5 = Total Fertilizer (kg/alq)	-0.138 (0.252)		X_{20} = Nitrogen Squared	-0.009 (0.045)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	
X_7 = Seed and def. (Cr$/alq)	0.041 (0.078)	0.059 (0.079)	X_{22} = Potash Squared	-0.013** (0.007)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-0.030* (0.026)
X_9 = Labor & Machinery (Cr$/alq)	0.072 (0.148)	0.126* (0.147)	X_{24} = Nitrogen & Potash	0.056* (0.042)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.008* (0.009)
X_{11} = Management Index II	0.289* (0.174)	0.108 (0.194)	X_7 = Seed & Def.	-0.010 (0.081)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	0.043* (0.053)
X_{13} = Crop Land (alq)	0.016 (0.064)	0.079* (0.073)	X_{10} = Total Expenses	
Standard Error of Estimate	0.305	0.300		60.077
Simple R^2	0.231	0.322		0.368
F - Ratio	1.400*	1.547*		1.217*

* Significant at 0.50 level ** Significant at 0.10 level

[a] 35 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 70 Sample B, Low Group, Cotton Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	4.284	4.641	Constant	
X_1 = Lime (tons/alq)	0.019 (0.036)	0.027* (0.038)	X_1 = Lime (tons/alq)	-0.00003 (0.005)
X_2 = Nitrogen (kg/alq)		-0.083 (0.148)	X_2 = Nitrogen (kg/alq)	-9.548* (7.666)
X_3 = Phosphate (kg/alq)		-0.034 (0.383)	X_3 = Phosphate (kg/alq)	0.371* (0.270)
X_4 = Potash (kg/alq)		-0.165 (0.296)	X_4 = Potash (kg/alq)	0.046 (0.777)
X_5 = Total Fertilizer (kg/alq)	0.053 (0.266)		X_{20} = Nitrogen Squared	0.020* (0.014)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.004 (0.024)
X_7 = Seed and def. (Cr$/alq)	0.027 (0.142)	0.026 (0.146	X_{22} = Potash Squared	-0.028* (0.021)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-0.060* (0.075)
X_9 = Labor & Machinery (Cr$/alq)	-0.015 (0.184)	0.029 (0.191)	X_{24} = Nitrogen & Potash	0.123** (0.067)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.017 (0.032)
X_{11} = Management Index II	0.050 (0.256)	0.009 (0.267)	X_7 = Seed & Def.	0.123* (0.132)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	-0.001 (0.054)
X_{13} = Crop Land (alq)	0.028 (0.096)	0.026 (0.098)	X_{10} = Total Expenses	
Standard Error of Estimate	0.481	0.493		66.906
Simple R^2	0.045	0.067		0.280
F - Ratio	0.221	0.234		0.712

* Significant at 0.50 level ** Significant at 0.10 level

[a] 35 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table Regional Soybeans Production Functions[a]

Variables	Regression Coefficients[b] Model III	Model IV	Variables	Reg. Coeff.[b] Model V
Constant	0.176	0.068	Constant	-46.267
X_1 = Lime (tons/alq)	0.034 (0.050)	0.041* (0.046)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.008 (0.060)	X_2 = Nitrogen (kg/alq)	0.340 (1.628)
X_3 = Phosphate (kg/alq)		-0.030 (0.053)	X_3 = Phosphate (kg/alq)	-0.065 (0.223)
X_4 = Potash (kg/alq)		0.041* (0.058)	X_4 = Potash (kg/alq)	0.031 (0.441)
X_5 = Total Fertilizer (kg/alq)	0.011 (0.056)		X_{20} = Nitrogen Squared	0.006* (0.006)
X_6 = Labor (Cr$/alq)	-0.002 (0.140)		X_{21} = Phosphate Squared	0.001* (0.001)
X_7 = Seed and def. (Cr$/alq)	0.127* (0.123)		X_{22} = Potash Squared	0.001 (0.002)
X_8 = Machinery (Cr$/alq)	0.163* (0.150)		X_{23} = Nitrogen & Phosphate	-0.013* (0.011)
X_9 = Labor & Machinery (Cr$/alq)			X_{24} = Nitrogen & Potash	-0.002 (0.003)
X_{10} = Operating Expenses (Cr$/alq)		0.595** (0.207)	X_{25} = Phosphate & Potash	0.000 (0.000)
X_{11} = Management Index II	0.309* (0.318)		X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land	-0.141* (0.183)		X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	-0.059 (0.121)	0.017 (0.085)	X_{10} = Total Expenses	0.176* (0.024)
Standard Error of Estimate	0.531	0.501		48.558
Simple R^2	0.174	0.216		0.657
F - Ratio	0.816	1.512*		6.384**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 40 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 72 Subregion, Soybean Production Functions

Variables	Regression Coefficients[c] Guaira[a] Model I	Guaira[a] Model II	Jard.-Sales & Other Areas[b] Model I	Jard.-Sales & Other Areas[b] Model II
Constant	-1.980	-2.415	25.598	29.867
X_1 = Lime (tons/alq)	0.012 (0.064)	0.051* (0.067)	-0.901** (0.391)	-0.630 (-----)
X_2 = Nitrogen (kg/alq)		0.019 (0.082)		
X_3 = Phosphate (kg/alq)		-0.032 (0.070)		-0.336 (-----)
X_4 = Potash (kg/alq)		0.035 (0.077)		0.370 (-----)
X_5 = Total Fertilizer (kg/alq)	0.008 (0.071)		0.120* (0.080)	
X_6 = Labor (Cr$/alq)				
X_7 = Seed and Def. (Cr$/alq)	0.166* (0.132)	0.200* (0.144)	0.040 (0.204)	-0.244 (-----)
X_8 = Machinery (Cr$/alq)				
X_9 = Labor & Machinery (Cr$/alq)	0.410* (0.303)	0.374* (0.348)	-0.539* (0.314)	-0.049 (-----)
X_{10} = Operating Expenses (Cr$/alq)				
X_{11} = Management Index II	0.369* (0.333)	0.473* (0.381)	-1.434** (0.696)	-2.032 (-----)
X_{12} = Crop Land/ Cultivated Land				
X_{13} = Crop Land (alq)	-0.010 (0.133)	-0.077 (0.168)	-1.538** (0.636)	-1.736 (-----)
Standard Error of Estimate	0.552	0.572	0.235	0.000
Simple R^2	0.203	0.242	0.911	1.000
F - Ratio	1.324*	0.920	1.705*	0.000

* Significant at 0.50 level ** Significant at 0.10 level

[a] 32 Observations [b] 8 Observations

[c] Numbers in parentheses are standard errors of regression coefficients.

Table 73 Sample A, High Group, Soybeans Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	-1.356	-1.923	Constant	42.201
X_1 = Lime (tons/alq)	0.000 (0.000)	-0.068* 0.068)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		0.043 0.102)	X_2 = Nitrogen (kg/alq)	0.516 (1.132)
X_3 = Phosphate (kg/alq)		0.064 0.099)	X_3 = Phosphate (kg/alq)	0.110 (0.206)
X_4 = Potash (kg/alq)		0.012 0.071)	X_4 = Potash (kg/alq)	-0.031 (0.254)
X_5 = Total Fertilizer (kg/alq)	0.003 (0.176)		X_{20} = Nitrogen Squared	-0.004 (0.006)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	
X_7 = Seed and def. (Cr$/alq)	0.051 (0.128)	0.066 0.150)	X_{22} = Potash Squared	0.0003 (0.0009)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	
X_9 = Labor & Machinery (Cr$/alq)	0.212 (0.348)	0.151 0.483)	X_{24} = Nitrogen & Potash	-0.001 (0.004)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	-0.0001 (0.0005)
X_{11} = Management Index II	0.499* (0.319)	0.611* 0.377)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	0.044 (0.174)	0.029 (0.224)	X_{10} = Total Expenses	0.004 (0.036)
Standard Error of Estimate	0.375	0.405		19.379
Simple R^2	0.392	0.484		0.406
F - Ratio	1.416*	0.939		0.684

* Significant at 0.50 level ** Significant at 0.10 level

[a] 17 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 74 Sample A, Low Group, Soybean Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	0.859	-0.393	Constant	-49.139
X_1 = Lime (tons/alq)	0.124* (0.072)	0.128* (0.077)	X_1 = Lime (tons/alq)	
X_2 = Nitrogen (kg/alq)		-0.126* (0.109)	X_2 = Nitrogen (kg/alq)	0.000 (0.000)
X_3 = Phosphate (kg/alq)		-0.182* (0.144)	X_3 = Phosphate (kg/alq)	0.098 (1.701)
X_4 = Potash (kg/alq)		0.206* (0.168)	X_4 = Potash (kg/alq)	1.065* (1.575)
X_5 = Total Fertilizer (kg/alq)	-0.067* (0.079)		X_{20} = Nitrogen Squared	0.108* (0.061)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	-0.004 (0.019)
X_7 = Seed and def. (Cr$/alq)	0.223* (0.196)	0.300* (0.210)	X_{22} = Potash Squared	-0.016* (0.010)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-0.108* (0.065)
X_9 = Labor & Machinery (Cr$/alq)	0.450* (0.213)	0.473** (0.223)	X_{24} = Nitrogen & Potash	0.000 (0.000)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.000 (0.000)
X_{11} = Management Index II	0.019 (0.448)	0.104 (0.503)	X_7 = Seed & Def.	
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	
X_{13} = Crop Land (alq)	-0.152* (0.135)	-0.152* (0.149)	X_{10} = Total Expenses	0.198** (0.029)
Standard Error of Estimate	0.544	0.546		0.5421
Simple R^2	0.391	0.462		0.781
F - Ratio	1.715*	1.502*		7.626**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 23 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.

Table 75 Sample B, All Groups, Soybean Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	-1.785	-2.563	Constant	20.158
X_1 = Lime (tons/alq)	-0.004 (0.042)	-0.006 (0.048)	X_1 = Lime (tons/alq)	0.016 (0.039)
X_2 = Nitrogen (kg/alq)		-0.0002 (0.0546)	X_2 = Nitrogen (kg/alq)	0.258 (1.059)
X_3 = Phosphate (kg/alq)		0.348* (0.365)	X_3 = Phosphate (kg/alq)	0.900* (0.955)
X_4 = Potash (kg/alq)		0.035 (0.361)	X_4 = Potash (kg/alq)	-0.648 (1.256)
X_5 = Total Fertilizer (kg/alq)	0.286* (0.155)		X_{20} = Nitrogen Squared	-0.004* (0.005)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	-0.005* (0.007)
X_7 = Seed and def. (Cr$/alq)	-0.041 (0.114)	-0.011 (0.122)	X_{22} = Potash Squared	-0.001 (0.011)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	0.008 (0.016)
X_9 = Labor & Machinery (Cr$/alq)	0.262* (0.262)	0.353* (0.330)	X_{24} = Nitrogen & Potash	-0.006 (0.009)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.007 (0.014)
X_{11} = Management Index II	0.311* (0.307)	0.276* (0.339)	X_7 = Seed & Def.	-0.118* (0.097)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	0.024* (0.023)
X_{13} = Crop Land (alq)	0.108* (0.135)	0.131* (0.166)	X_{10} = Total Expenses	
Standard Error of Estimate	0.363	0.371		18.698
Simple R^2	0.322	0.371		0.434
F - Ratio	1.428*	1.181*		0.768

* Significant at 0.50 level ** Significant at 0.10 level

[a] 25 Observations
[b] Numbers in parentheses are standard errors of regression coefficients.

Table 76 Sample B, Other Groups, Soybean Production Functions[a]

Variables	Regression Coefficients[b] Model I	Model II	Variables	Reg. Coeff.[b] Model III
Constant	1.575	4.506	Constant	-5.892
X_1 = Lime (tons/alq)	0.177* (0.124)	0.297** (0.139)	X_1 = Lime (tons/alq)	0.720* (0.630)
X_2 = Nitrogen (kg/alq)		0.229* (0.289)	X_2 = Nitrogen (kg/alq)	0.000 (0.000)
X_3 = Phosphate (kg/alq)		-0.050 (0.085)	X_3 = Phosphate (kg/alq)	-0.775 (1.184)
X_4 = Potash (kg/alq)		0.069 (0.128)	X_4 = Potash (kg/alq)	-0.257 (0.754)
X_5 = Total Fertilizer (kg/alq)	0.040 (0.095)		X_{20} = Nitrogen Squared	0.000 (0.000)
X_6 = Labor (Cr$/alq)			X_{21} = Phosphate Squared	0.006 (0.009)
X_7 = Seed and def. (Cr$/alq)	0.731** (0.357)	0.915** (0.347)	X_{22} = Potash Squared	0.002 (0.003)
X_8 = Machinery (Cr$/alq)			X_{23} = Nitrogen & Phosphate	-0.011* (0.016)
X_9 = Labor & Machinery (Cr$/alq)	0.124 (0.295)	0.086 (0.290)	X_{24} = Nitrogen & Potash	0.000 (0.000)
X_{10} = Operating Expenses (Cr$/alq)			X_{25} = Phosphate & Potash	0.000 (0.000)
X_{11} = Management Index II	-0.340 (0.679)	-0.848* (0.704)	X_7 = Seed & Def.	0.351** (0.035)
X_{12} = Crop Land/Cultivated Land			X_9 = Labor & Machinery	-0.017 (0.060)
X_{13} = Crop Land (alq)	0.058 (0.186)	0.088 (0.175)	X_{10} = Total Expenses	
Standard Error of Estimate	0.676	0.635		34.322
Simple R^2	0.471	0.650		0.963
F - Ratio	1.188*	1.391*		19.528**

* Significant at 0.50 level ** Significant at 0.10 level

[a] 15 Observations

[b] Numbers in parentheses are standard errors of regression coefficients.