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A LINEAR PROGRAMMING ANALYSIS OF OPTIMUM FARM ORGANIZATION IN THE MUNICIPIOS OF SAO JOAQUIM DA BARRA, ORLANDIA, AND SALES DE OLIVEIRA, STATE OF SAO PAULO, BRAZIL

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To the Memory of My Parents

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ABSTRACT

Pellegrini, Luiz Matteu. M.S., Purdue University, January 1969. A Linear Programming Analysis of Optimum Farm Organization in the Municipios of Sao Joaquim da Barra, Orlandia, and Sales de Oliveira, State of Sao Paulo, Brazil. Major Professor: Dr. G. Edward Schuh.

The problem of farm reorganization has been generally recognized as deserving priority in development programs for underdeveloped countries. Farm reorganization possibilities are amenable to solution with economic principles. This study is concerned with the problem of planning economically efficient farm organization in the Northern part of the State of Sao Paulo.

The conceptual framework underlying this study is a linear programming approach to the theory of the firm. Twelve linear programming models were developed for different types and sizes of farms in two different regions. Data to build the empirical models was obtained from a survey and other sources.

These models are short-run and composed of twenty linear equations and thirty-six activities. The activities are transfer permanent labor, hired temporary labor, borrowed operating capital, rent-out pasture, crop production, dairy, hog fattening, and selling of farm products. Crop production was allowed to be done either with tractor or with animals, and the crops considered are those of greatest commercial importance in the region; namely, corn, edible beans, sugar cane, rice, cotton, peanuts, and soybeans. The models given the assumptions and specifications give the optimal plans.

In general, the results indicate that farmers should employ more labor, which under the conditions of the models enters as temporary labor. It was also found that mechanization is not a viable activity in any of the optimal plans.

As compared to the actual farm organization, the optimal plans tend to be more specialized with sugar cane, peanuts, and rice being the main crops and dairy being the only productive livestock.

The sensitivity analysis carried out for the twelve optimal plans indicate that the activities are fairly insensitive to changes in the parameters. However, some crop prices and initial resource availabilities are sensitive to those changes.

The results of this study stress the need for more research of this nature, provided that the resources are not being allocated, as well as the production combined, in an economically efficient manner. The results also can provide the farmer with basic knowledge on which to base decision-making.

CHAPTER I

INTRODUCTION

In many emerging nations, the development of the agricultural sector is an important issue. Agriculture tends to provide the largest portion of the GNP and the largest portion of employment opportunities in the economy. However, for many years, the contributions of the agricultural sector were neglected by development economists and government policy makers.

More recently, however, both economists and policy makers have given more attention to the role of agriculture in the process of economic development. Apparently, the main reasons for this shift in emphasis are the following:[1/]

1. Rapid increases in population that were outrunning food supplies,
2. Prices of food items increasing faster as compared to the other components,
3. Widening foreign exchange gaps that result from reduced farm exports, which in turn are the results of increasing domestic consumption, and

1/ Schuh, G. E. and Tollini, H., "Agriculture and Economic Development," Instituto de Economia Rural, UREMG, Vicosa, Brazil, 1964, pp. 1-5.

4. Failure to obtain sustained rates of economic growth through programs which concentrated on pushing industrialization to the neglect of the agricultural sector.

It is being increasingly recognized that the agricultural sector can make a substantial contribution to economic development under certain conditions.2/ This contribution is generally recognized to take place in at least five ways:3/

1. The release of labor to the non-farm sector,
2. A source of savings or capital formation for the total economy,
3. A rise in the real income of all members of society by supplying food at lower prices, which also has a strong income distribution effect,
4. An enlargement of the market for products produced in the non-farm sector, and
5. A source of foreign exchange earnings.

Given these potential contributions, it follows that, as the agricultural sector develops -- that is, becomes technically and economically efficient -- its contribution to general development can be increased.

2/ For a systematic analysis of the conditions under which agriculture or industry should be stressed, see Flanders, June, "Agriculture vs. Industry in Development Policy: The Planner's Dilemma Reexamined," Unpublished Mimeo, Purdue University, 1968.

3/ Schuh and Tollini, *op. cit.*, pp. 1-5.

If the agricultural sector then is to maximize its contribution to the welfare of the economy, given the technical efficiency possibilities and perfectly competitive markets, the allocation of resources in agriculture must be economically efficient.

To the extent that maximizing welfare has priority as a policy goal, it becomes important that the resources in the agricultural sector are allocated in an economically efficient manner. An important dimension of this is the organization of resources within the farm.

The Problem

This research is concerned with the problem of formulating guidelines for planning economically efficient farm organization in three counties (municipios) of the state of Sao Paulo, Brazil. As Table 1.1 indicates, Sao Paulo is an important agricultural state in Brazil. Slightly over 20 percent of the total internal income from agriculture for the country comes from this state, even though other states are much larger geographically.

The particular area chosen for study is one in which the former agriculture, which was extensive and primarily livestock, is being replaced by a more intensive and specialized one. This transformation is probably due to a number of factors. For one thing, the region has soil qualities that permit a more intensive use of it. In recent years,

Table 1.1. Internal Income from Agriculture, Selected States and Regions, 1964, in NCr$1,000.

	Value	Percent of Total
Sao Paulo	1,072,753	20.46
Minas Gerais and Espirito Santo	778,853	14.85
Northeast[a/]	776,252	14.80
Rio Grande Do Sul	681,689	13.00
Mato Grosso and Goias	407,325	7.76
Bahia	314,395	5.99
Others[b/]	1,211,790	23.14
Total	5,243,057	100.00

a/ Rio Grande Do Norte, Ceara, Pernambuco, Alagoas Paraiba, and Sergipe.

b/ Acre, Amazonas, Para, Maranhao, Piaui, Guanabara, Rio de Janeiro, Parana, Santa Catarina.

Source: O Conselho Nacional de Estatistica.

improvements in transportation facilities in the state have been great. The area is favorably located with respect to market opportunities as a result of the proximity of highways leading to major consumption centers such as Sao Paulo, Rio de Janeiro, Brasilia, Belo Horizonte, Curitiba. In addition, the rapid industrialization of Sao Paulo has undoubtedly imposed substantial adjustments on the agricultural sector.[4/]

The major commercial agricultural products of the study region are corn, rice, and dairy cattle. The topography is appropriate for the mechanization of crop production. The use of fertilizer is large in relation to other areas of Brazil, but little or no evidence is available concerning the rationality of its usage.

Only limited studies have been made of the optimality of resource use in Sao Paulo agriculture.[5/] Such studies as are available suggest, however, that the resources are not being employed in optimal combination, given the product and resource prices and the level of technical efficiency. For the particular region considered in the present study, little is known concerning how to advise decision-makers in planning farm organizations which are economically efficient.

4/ W. H. Nicholls, "The Transformation of Agriculture in a Semi-Industrialized Country: The Case of Brazil," Conference on the Role of Agriculture in Economic Development, December 1967.

5/ See Review of Literature

The problem, then, is to determine what constitutes an economically efficient selection of enterprises and combination of resources. The present research is formulated under the assumption that the decision-maker's primary goal is to maximize their farm income. The general objective of this study is to provide useful knowledge in the form of guidelines for farm firms desiring to adjust their farm organization towards the norm of economic efficiency.

To provide this useful knowledge, it is not practical to analyze the organization of every farm firm in the region. Instead, this study will determine the optimal farm organization for representative farms, given the resources available, the state of technology, and the product prices and production costs. The results obtained for these representative farms may in turn be generalized to similar farms in the region.

This study is conditional normative in that its purpose is to estimate what should be done to attain economic efficiency (maximum income to fixed resource) of farm organization under a given set of conditions. This is in contrast to a positive approach which would estimate what is done within the context of the diverse goals and expectations of the decision-makers.

Use of the Results

The knowledge provided by this study can have direct application in a number of important ways. For example, the results in terms of suggested farm organizations can be directly used by farmers in the regions studied. In addition, they can serve as a guide to extension personnel in adult education programs. Sao Paulo has a well-organized extension service in its Casas de Lavoura (crop houses). The broad objective of this extension service is to improve the economic welfare of the people with whom they are working in the rural population. The results of the present research will not only help the extension personnel in orienting farmers on their own farm organizations, but will also be useful as a vehicle for teaching the principles of farm management.

At a somewhat different level, the study can be useful by providing a conceptual frame of reference for the acquisition of information necessary to attain that combination of enterprises and combination of resources that will maximize net revenue -- the optimum plan. This frame of reference and information will be useful not only to the extension personnel, but also to researchers who are dedicated to the improvement of rural welfare.

At a third level the results will be useful to policy makers. Although the analysis is developed with micro-units, the results can have important macro-implications.

For example, they can indicate the need for general education programs to improve resource use, or they can indicate the need of general resource problems such as a scarcity (or excess) of capital and or labor. Implications at this level will be considered in the analysis which is to follow.

In summary, the results can be useful in improving the welfare of farm families by suggesting how they can improve their farm organization to increase net income. In addition, it can suggest to policy makers the actions they might take in order to facilitate this re-combination of resources. The improvement in resource use will increase the output from a given set of resources, and, therefore, increase general well-being in society so long as full employment of resources is maintained. Finally, the study can provide a foundation for future research.

Objectives

The broad objective of this research is to supply a set of economic guidelines which would constitute an economically efficient organization of the farm firms in the region. The specific objectives of the study are as follows:

1. To develop empirical models which characterize the farm organization of 12 farms of different sizes and type for the study region. These farms

will be representative of those operating in the study area during the crop year of 1966 to 1967.

2. To determine the optimal farm organization for each of these 12 farms, given the initial conditions concerning the resources available, the state of technology, product prices, and production costs.
3. To evaluate the stability of these optimal farm organizations in a dynamic situation in which the initial conditions are altered.
4. To examine the degree to which the existing organization of farm in the region deviated from the optimal farm organization.
5. To analyze the implications of the results obtained for private and public actions.

General Procedures

The conceptual framework for this research is formed by a linear programming approach to the theory of the firm. Data for the construction of the empirical models was obtained from a survey of 79 farms in the study area (25 in Sao Joaquim da Barra, 31 in Orlandia, and 23 in Sales de Oliveira), from interviews with people familiar with the area, and from published and unpublished material.[6/]

6/ A description of the sampling procedure is presented in Appendix A.

Tests of homogeniety[7/] were used in developing the representative farms to be programmed. These tests indicated that the farms from Sao Joaquim da Barra and Sales de Oliveira could be grouped together, while those from Orlandia were different from the others in a number of characteristics. The test also indicated substantial differences among the farms according to their size. On these considerations, and the judgment of the researchers, it was decided to develop 12 representative farms based on region, size, and whether the farm was primarily livestock or crop in its organization.[8/]

The farms from the sample were then classified into these 12 representative farms. The number of farms in each classification is presented in Table 1.2. Resource endowments for each representative farm were determined by the average of the farms in each classification. Coefficients for the programming analysis were estimated from the sample data, and outside sources where necessary.[9/]

For each one of the 12 farms, empirical models were synthesized. Based on the empirical models so developed, and utilizing the linear programming technique, the optimal farm organization for each one of the farms was obtained.

7/ A description of the tests and the results obtained are presented in Appendix B.

8/ The latter distinction is based on the assumption that the managerial skills are basically different between these two types of operations.

9/ See Chapter II for more detail.

Table 1.2. Distribution of Farms Sampled Among the Representative Farms.

	Region 1[a]		Region 2[b]		
	Crop	Livestock	Crop	Livestock	Total
Small	16	8	13	8	45
Medium	7	0	0	0	7
Larger	7	5	4	5	21
Extra Large	4	1	1	0	6
Total	34	14	18	13	79

a/ Region 1: Sales de Oliveira and Sao Joaquim da Barra.

b/ Region 2: Orlandia.

The linear programming solutions were obtained using Rades' LP program on Purdue University's CDC 6500 computer.

Related computations in the above programs provided the basis for an analysis of the stability of these farm organizations in the face of changes in product prices, production costs, technology and resource availability.

As a final part of the analysis, recommendations are derived in terms of general farm reorganization. Implications are then derived in terms of pertinent policy measures, and suggestions are made for future research.

The Study Region

The study region is formed by three counties: Orlandia, Sao Joaquim da Barra and Sales de Oliveira. These three counties are part of the geographical area of Ribeirao Preto, which is located in the Northern part of the State of Sao Paulo.

The soil of this geographical area is very fertile, part of it being Terra Roxa (the municipio of Ribeirao Preto) and part Arenito Botucatu, Serie Franca. The soils in the study region are principally of the latter type.

The topography is predominantly flat, permitting the use of machinery and implements. The region is located near the great consuming centers, which gives it some advantages over many other regions in Sao Paulo. The region is connected to Sao Paulo, Campinas, Ribeirao Preto, Curitiba and the Minas Triangle by paved roads.

Agriculture in this region, located in the Alta Mogeana, began during the coffee expansion period. However, as soon as coffee found its way down to the Southwestern part of Sao Paulo and the Northwestern part of Parana, this region diversified its agriculture.

The production of coffee moved because of low prices, and also because in the new area, better soils and more favorable climatic conditions were found. An important consideration was the fact that the soils of the "old region" were completely depleted.

In recent years, the main commercial agricultural products in the geographical area are corn, sugar cane, rice, cotton, soybeans, edible beans, and peanuts (see Table 1.3). Livestock includes dairy, swine, and work animals.

The distribution of land biddings in the study area is characterized by small farms (Table 1.4). Sixty-five percent of the total number of farms in the region have less than fifty hectares, and 35 percent have more than fifty hectares. Only 15 percent of the total are greater than 200 hectares.

Characteristics of the Representative Farms

Data on the percent of income that comes respectively from crops and livestock for the representative farms are presented in Table 1.5. It is important to notice that the

Table 1.3. Major Agricultural Crops, Geographical Area of Ribeirao Preto, Sao Paulo, 1966 to 1967.

Crop	Units	Production	Area in Hectares
Corn	1000 sacks	5962	169351
Sugar Cane	1000 tons	7061	99220
Rice	1000 sacks	1294	96292
Cotton	1000 arrobas[a/]	6243	51062
Soybeans	1000 sacks	222.9	8857
Edible Beans	1000 sacks	44	6001
Peanuts	1000 sacks	292	3582

a/ 1 arrbor = 15 kilograms

Source: Secao de Previsao de Safras, Divisao de Economia Rural, Sao Paulo.

Table 1.4. Distribution of Agricultural Properties, Study Region, Sao Paulo, 1966.

Classes Hectares	Number of Properties				Percent of Total
	Orlandia	Sales de Oliveira	Sao Joaquim da Barra	Total	
5 - 50	83	136	223	442	65
51 - 200	26	50	65	141	20
201 - 500	10	22	21	53	8
501 - 1000	6	11	15	32	5
1001 - infinity	0	5	7	12	2
Total	125	224	331	680	100

Source: Registration Files in the County Tax Office of Orlandia, Sales de Oliveira, and Sao Joaquim da Barra.

Table 1.5. Percent of Income[a] from Crops and Livestock, and Income per Hectare, by Representative Farm.

Region[b]	Type	Size	Crop	Livestock	Income Per Hectare NCr$
			(percent)	(percent)	
1	Crop	Small	94.45	5.55	323.51
1	Crop	Medium	85.95	14.05	805.89
1	Crop	Large	91.57	8.43	1632.14
1	Crop	Ex.Large	84.50	15.50	2176.00
2	Crop	Small	91.61	8.39	689.07
2	Crop	Large	80.50	19.50	1464.75
2	Crop	Ex.Large	82.00	28.00	1065.00
1	Livestock	Small	49.37	50.63	837.37
1	Livestock	Large	41.40	58.60	1036.03
1	Livestock	Ex.Large	23.00	67.00	974.00
2	Livestock	Small	41.25	58.75	898.00
2	Livestock	Large	45.20	54.80	1030.60

a/ Gross sales.

b/ Region 1 includes Sao Joaquim da Barra and Sales de Oliveira. Region 2 is the municipio of Orlandia.

Source: Sample

crop farms tend to be much more specialized in crop production than do the livestock farms in livestock production. In the latter case, only one representative farm receives more than 60 percent of its income from livestock.

Data on the income per hectare by representative farm is presented in the same table. To the extent that income per hectare serves as a measure of the intensiveness of exploration, these data show that the crop farms tend to be more intensively explored than do the livestock farms. By the size of the farm, there seems to be no strong relationship. As the size of crop farm increases in Region 1, the intensity of exploration increases. In Region 2, however, the middle sized-group tends to be more intensively operated. For the livestock farms, the middle size group was most intensively operated in Region 1, but in Region 2 it was the large size group that was most intensively operated. (Table 1.5).

Data on land use by representative farms are presented in Table 1.6. In general the livestock farms tend to have a larger fraction of their land in pasture than do the crop farms. Within each region and by type of farm, there is also an inverse relation between the size of farm and the fraction of land in crops. It is interesting to note also that three of the representative farms have substantial amounts of idle land. (Table 1.6).

Table 1.6. Land Use by Representative Farm.

Region	Type	Size	Cropland	Pasture	Idle	Total
			(percent)	(percent)	(percent)	(percent)
1[a/]	Crop	Small	66	25	9	100
1	Crop	Medium	46	34	20	100
1	Crop	Large	40	48	2	100
1	Crop	Ex.Large	32	60	8	100
2[b/]	Crop	Small	36	58	6	100
2	Crop	Large	34	62	4	100
2	Crop	Ex.Large	12	87	1	100
1	Livestock	Small	40	60	0	100
1	Livestock	Large	25	62	13	100
1	Livestock	Ex.Large	1	99	0	100
2	Livestock	Small	19	75	6	100
2	Livestock	Large	13	69	18	100

a/ Sao Joaquim da Barra and Sales de Oliveira
b/ Orlandia

Source: Sample

Labor for farm operations tend to be supplied by the family, by laborers who work permanently on the farm the year around, and by laborers who are hired in a temporary basis. Data on the fraction of labor coming from each of these sources is presented in Table 1.7. Within each type of farm for each region there is an inverse relation between the size of farm and the fraction of labor supplied by the family. However, it is more difficult to generalize about the fraction of labor provided by permanent and temporary labor, since it varies among the types of farm and regions (Table 1.7).

Capital owned by the farmers is in the form of land, machinery, and livestock. Data on the fraction of capital in each of these forms is presented in Table 1.8. As these data indicate, the principal capital input is land. Second in importance is machinery, which tends to be more important than livestock even in the livestock farm. The livestock farms do tend to have a larger fraction of their capital in the form of livestock than do the crop farms. Beyond this, there is little systematic that can be said.

Review of Literature

Studies which use the modern tools of economic analysis either for diagnostic purposes or for normative recommendations are extremely limited in Brazil. The only center which has attempted to do empirical work on any scale with

Table 1.7. Composition of the Labor Force by Representative Farm.

Region	Type	Size	Family	Permanent	Hired[a]
			(percent)	(percent)	(percent)
1[b]	Crop	Small	56	21	23
1	Crop	Medium	40	37	22
1	Crop	Large	18	34	48
1	Crop	Ex.Large	4	84	12
2[c]	Crop	Small	58	23	19
2	Crop	Large	15	66	19
2	Crop	Ex.Large	0	61	39
1	Livestock	Small	67	26	7
1	Livestock	Large	50	32	18
1	Livestock	Ex.Large	0	100	0
2	Livestock	Small	36	23	41
2	Livestock	Large	19	45	36

a/ Hired labor is mostly used during the harvesting period (May and June).

b/ Sao Joaquim da Barra and Sales de Oliveira

c/ Orlandia

Source: Sample

Table 1.8. Composition of Capital by Representative Farm.

Region	Type	Size	Land	Machinery	Livestock[a/]
			(percent)	(percent)	(percent)
1[b/]	Crop	Small	66	25	9
1	Crop	Medium	59	26	15
1	Crop	Large	75	16	9
1	Crop	Ex.Large	70	20	10
2[c/]	Crop	Small	70	22	8
2	Crop	Large	65	26	9
2	Crop	Ex.Large	75	17	8
1	Livestock	Small	54	29	17
1	Livestock	Large	64	23	13
1	Livestock	Ex.Large	70	0	30
2	Livestock	Small	59	26	15
2	Livestock	Large	64	20	16

a/ 90 percent from dairy and 10 percent from swine.
b/ Sao Joaquim da Barra and Sales de Oliveira
c/ Orlandia

Source: Sample

these new methods is the Institute of Rural Economics located in Vicosa. Most of these studies have dealt with the agriculture in Minas Gerais.

To the best of the author's knowledge, only three studies have attempted to estimate an empirical production function and use this to analyze resource use in Sao Paulo. The first of these was made by The Food and Agriculture Organization of the United Nations,[10/] to analyze the resource use in the production of coffee.

The study was carried out on a sample of 1,991 farms in the State of Sao Paulo. Two equations were estimated according to a composite model which contained Cobb-Douglas type and asymmetric parabola production functions.

The coefficients of determination obtained were not very significant -- only 20 to 60 percent of the variation in output was explained. The regression coefficient for labor had a very low statistical significance, even though this factor is known as the most important in coffee production. On the other hand, the effect of fertilization proved to be important.

The other conclusions were quite logical -- the new variety "Mundo Novo" and the best soil type "Terra Roxa" yielded higher returns to the use of the factors.

10/ Organizacao de Alimentacao e Agricultura das Nacoes Unidas, "Analise Estatistica dos Fatores que Afetam os Rendimentos Agricolas do Cafe no Estado de Sao Paulo," Agricultura em Sao Paulo, Secretaria da Agricultura, Sao Paulo, Brazil, June 1961.

Veiga[11] treated the problem of resource use and productivity, at the farm level in the county of Jaguariuna, State of Sao Paulo. The author's primary objectives were to estimate the relationship between resource use in production and the value of farm output, to determine the optimum level of resource use and gain insight into probable adjustments in resource use patterns. To achieve the objectives, Cobb-Douglas type production function was accepted as the best estimate of the relationship of interest.

Veiga found that too much land, labor, and capital investment in equipment were employed. Investments in buildings, productive livestock, draft livestock and current expenditures were less than optimal.

Zagatto, et. alii,[12] also used a Cobb-Douglas type production function to determine the optimum level of resource use in sugar cane production for the County of Rio das Pedras, State of Sao Paulo. They used land and fertilizer as the variables to estimate the production function. As Veiga, they also found that the two resources mentioned were not being used at the optimal level.

Studies which use linear programming techniques are even more limited than those using production functions.

11/ Alberto Veiga, "Use and Productivity of Agricultural Resources - Jaguariuna County, Sao Paulo, Brazil," Unpublished M.S. thesis, Purdue University, 1966.

12/ A. G. Zagatto, et. alii., "Produtividade Marginal e Uso de Recursos na Lavoura Canavieira do Municipio de Rio das Pedras, Sao Paulo," Unpublished Mimeo, USP, Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, Sao Paulo, 1965.

For example, Vicosa has carried out only two studies which have used this important tool. The Rural University of Rio Grande do Sul has used it somewhat more extensively, although we were not able to obtain details on this.

The author was able to find only one study which used linear programming to analyze farm organization in Sao Paulo. Panegides[13/] used linear programming to evaluate current coffee policy in Sao Paulo. Using a representative farm, he examined the role of coffee in the farm organization given the present price incentives. He found that the returns to coffee production was so much greater than those provided by other enterprises that, even with present efforts to reduce coffee plantings, they are likely to expand in the immediate future.

13/ S. Panegides, "Coffee Erradication and Diversification of Brazilian Agriculture," Unpublished Mimeo, IPEA, Ministerio do Planejamento, Rio de Janeiro, Brazil, 1 968.

CHAPTER II

METHODOLOGY AND EMPIRICAL MODELS

This chapter is divided into three parts. The first part presents a brief summary of the basic methodology of linear pgoramming. The second part explains sensitivity analysis and its use in programming analysis. The final part describes the information used in constructing the models and specifies the relationships within the models.

Linear Programming

This study is based on the assumption that the farmers' primary objective is to maximize their incomes, according to the resources available, product prices, production costs and given some level of technology.

The basic methodology is that of linear programming.

Linear programming is a mathematical technique that optimizes a linear objective function of several variables which are subject to linear inequality or equation constraints. The logic and assumptions of linear programming and its use in farm planning will only be reviewed, since the mathematics of computing the linear programming solutions is adequately explained in the literature.1/

1/ For example, see E.O. Heady and W. Chandler, Linear Programming Methods, Iowa State University Press, Ames, Iowa, 1961.

In the short-run farm planning situation, farm enterprises (or production activities) compete for the services of the farm firm's fixed stock of resources (land, labor and capital). These resources embody the services which are the inputs of the production activities. Each production activity represents one method or technique of transforming resources into one or more products.

The concept of production activity as used in this research is distinguished by the constancy of the internal ratio of inputs and outputs as the production level of the activity changes. The levels at which each production activity is to operate are the unknowns of the farm planning problem. The objective is to select from a finite set the most profitable combination of production activities within the constraints imposed by the available resources, given the costs and returns of the activities. That combination of production activities which fulfills the above objective represents the optimal farm organization which maximizes the expected returns to the fixed resources.

Linear programming provides a systematic mathematical procedure for simultaneous consideration of all possible combinations in one operation. This procedure consists of two parts: (1) find the set of all feasible combinations of activities which satisfy the constraints imposed by the resources available in the model and (2) select that particular one from the set that optimizes the objective function, and for this particular study, will maximize the farm income.

Linear programming has three characteristics: (1) a linear objective function, (2) a set of linear constraints, and (3) non-negative constraints. These characteristics can be expressed in matrix notation as follows:

Maximize	$f(X) = CX$
Subject to constraints	$AX \quad P_o$
and	$X \quad 0$

where

X is an n - component vector of the unknowns in the model - the levels of production activities;

C is an n - component row vector of the costs and returns, the C_j's of each production activity;

A is an n x m matrix of the technical coefficients associated with the production activities;

P_o is an m - component column vector of the available amounts of each constraining resource; and

0 is an n - component column vector of zeros.

There are certain mathematical assumptions inherent in the linear programming model which must be imposed on the problem to be analyzed. The realism of the linear programming solution depends on how closely the empirical situation is approximated within the limits of these assumptions.

The assumptions are as follows:

(1) Additivity: The activities must be additive, which means that when one or more activities are used simultaneously, their total output of product and input of resources must be the sum of their individual outputs and inputs.

(2) Linearity: The activities have to be linear; that is, the returns to scale within each activity are constant.

(3) Divisibility: To allow for the use and production of fractional quantities, the resources and products are considered to be infinitely divisible.[2/]

(4) Finiteness: There exists a finite limit to the number of alternative activities and to the resource constraints which need to be considered.

(5) Single-value expectations: Resource supplies, technical coefficients, and prices are single-value expectations; that is, it is assumed that they are known with certainty.

2/ Perfect divisibility of inputs and output is assumed in linear programming; therefore, the figures in the optimum plan may not consist only of whole numbers. This means that the optimum organization as developed by linear programming cannot always be followed precisely because in real life certain inputs and outputs cannot be broken into fractional units.

Sensitivity Analysis

Linear programming can furnish related computations in addition to the solution levels of the production activities which define an optimal farm organization. These related computations provide useful information concerning the sensitivity of the optimal farm organization. Sensitivity analysis refers to the analysis of the effect on the optimal solution of the linear programming model of changes in the parameters; that is, the technical coefficients, costs and returns, and resource availabilities.

The model used herein is basically a short-run model in the sense that the farm is programmed for a one-year period, where some resources (like land, for instance) are not allowed to vary. Because of its static nature, sensitivity analysis is also useful in indicating the implications of dynamic conditions where expectations are not single-valued. The optimal solution is considered stable (or insensitive) if "large" changes in the parameters of the model are necessary before a change in the optimal solution will occur. The question of how great a change is considered large depends on the variability of that particular parameter over time.

In many cases the information obtained through sensitivity analysis is as valuable as the optimal solution itself. Among the reasons for the importance of sensitivity analysis, Dantzig points out three as being most important:[3/]

(1) The stability of the optimal solution under changes of parameters (technical coefficients, costs and returns, and resource availabilities) may be critical. That is, given an optimal solution, a slight variation of a parameter in one direction may result in a large unfavorable difference in the profit realized by this solution relative to an alternative solution, while a large variation in the parameter in another direction may result in only a small difference. When there are certain inherent variabilities in production activities and resources not taken into account in the model, such as personal preferences, peculiarities of farm arrangement, risk, and uncertainty considerations, managerial abilities, it may be desirable in considering the difference in profit, to move away from the optimal solution in order to achieve a solution less likely to require essential modification.

(2) The values of the parameters may be to some extent controllable, and in this case it is useful to know the effects which result from changing these values.

(3) Even though the parameters are not controllable, the estimates for their values may be only approximate,

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3/ George B. Dantzig, Linear Programming and Decisions, (Princeton, New Jersey: Princeton University Press), 1963, pp. 266-267.

making it important to know in what ranges of these values the solution is still optimum. If it turns out that the optimum solution is extremely sensitive to their values, it may become necessary to obtain better estimates.

The related computations (referred to above) that are available in the linear programming solution are the shadow prices, the cost and return ranges, and the resource availability ranges. The objective of the following is to discuss the economic interpretations of these related computations according to the sensitivity analysis and the farm planning problem.

Shadow prices represent imputed marginal values in the linear programming model. The interpretation of shadow price is different depending on whether it is associated with a "real" or "disposal" activity. An activity is said to be real if it represents actual production relationships. A disposal activity allows for the non-use of resources.

Shadow prices associated with the resource disposal activities represent the "marginal value products" of the corresponding resources. A non-limiting resource, one which is not totally employed in the optimal solution, has a shadow price (marginal value product) of zero, since a one-unit change in the availability of that particular resource would not affect profit.

A positive shadow price on the resource disposal means that a one-unit increase in that resource disposal, with the resource supply remaining constant at some level, would decrease profits by an amount equal to the marginal value product (shadow price). Conversely, a positive marginal product associated with a limiting resource indicates that a one-unit increase (decrease) in resource supply, could allow an addition to (reduction of) profits.

The marginal value product gives an indication of the increases in profit possible through acquisition of additional resources. For example, if capital is limiting, it would be profitable to borrow capital so long as the cost to borrow it is less than its marginal value product. The marginal value product of a resource is valid only for the resource availability range (discussed later in this section) of this resource; above this range the marginal value product is lower, and below this range it is higher.

A shadow price associated with a real activity indicates the penalty cost of including one unit of this production activity in the farm organization designated as optimum. The real activities that are components of the optimal solution have a zero shadow price (penalty cost).

Penalty cost is a concept which refers to adjusting the activity combination to maximize profit when one unit of a given activity not included in the initial optimal solution is added to the farm plan. These penalty costs are useful as indicators of the stability of the optimal farm organization with regard to changes in the costs or returns of the activities not included in this optimal organization. They also indicate for the corresponding activity the amount by which its return must increase, or its cost decline, to bring this activity into the optimal farm plan without sacrificing profit. A large penalty cost suggests that a one-unit addition of the corresponding real activity would imply a large sacrifice in profit, while a small penalty cost suggests the reverse.

The resource availability range for a particular resource provides the range over which the quantity of that particular resource can vary, other things being constant, without changing the set of activities in the optimal solution. From this, we can say that the resource availability ranges indicate the sensitivity of the optimal farm organization to changes in the set of resources available to the farm firm.

The marginal value product (shadow price) of that resource is constant within the limits of a resource availability range. The cost and return ranges also permit an analysis of the stability of the optimal solution. They define how much the cost or return per unit of an activity in the optimal solution can vary, *ceteris paribus*, without any change in the set of activities which form the optimal farm organization.

The Empirical Models

Twelve linear programming models were developed. These include one for each of the twelve representative farms. Each model consists of 20 equations and 36 activities. The models are static, short-run and will maximize annual returns to the farmer's stock of fixed resources. The twelve models are basically the same, with only the technical coefficients and resource availabilities varying from model to model.[4/]

In the following sections there is a general description of how these models were synthesized. The types of information needed for the linear programming models include:

1. An inventory of the resources available for the particular farm.
2. The production activities which are of commercial importance in the area of study.
3. The costs of and returns to each activity.
4. The technical coefficients -- the quantity of each resource required per output unit of each activity.

Resources Available

The basis for determining the inventory of resources available for each of the twelve synthesized farms studied was the survey of 79 farms in Sao Paulo. The average resource situation for each "class" was taken as typical of

4/ Resource availabilities, yields, and cost and returns.

the farms in that "class" and was used as the set of resources available in the linear programming model for that size and type of representative farm.

The resources included in each of the twelve farms are hectares of cropland and pasture land, man-days of permanent labor, owned capital, and borrowed capital. These data were taken from the respective questionnaires. The total man-days of permanent labor available was reduced by 10 percent to account for other services needed in farms which did not show up in the model.

Production Activities Considered

The alternative production activities included in the linear programming models are those which were of greatest commercial importance in the study regions. The crops considered included corn, edible beans, sugar cane, rice, cotton, peanuts, and soybeans. These could be raised either using tractors or draft animals (hereafter referred to as mechanized and non-mechanized, respectively).

The livestock enterprises considered are dairy and a swine fattening activity. The labor used in the production activities is provided from the stock of permanent labor. For crop production, hired temporary labor could be used if needed, but for the livestock activities it was assumed that hired temporary labor did not possess the skills necessary to care for them.

Cost and Returns

The cost and returns for the linear programming models are determined from data reported in the questionnaires, due to the limited amount of other farm price information available. Due to inflation, all costs and returns are evaluated as of May, June, and July, 1967, in order to avoid distortion of their relative values.

The costs and prices for crop and livestock products are average values synthesized from the questionnaires. The production costs include only variable costs associated with each variable, namely, depreciation, interest, repairs, taxes, insurance, seeds, fertilizers, pesticides, feed, medications, and veterinary care for livestock. Overhead costs of fixed resources which continue regardless of the farm organization do not affect short-run farm planning. All costs and returns are measured in terms of new cruzeiros.

No disposal or salvage prices are specified for the resources in the models. However, the marginal value product (shadow price) associated with each resource in the linear programming solution does give the value above which the firm will not employ all of the available resource in the activities specified in the model. For example, if the reservation price or opportunity cost of permanent labor is above the marginal value product, all or part of it will be withheld from employment on the farm.

Technical Coefficients

The technical coefficients for the production activities are determined from the information obtained from the questionnaires and from published and unpublished material by Brazilian and United States authors. The technical coefficients for labor use are the same for all twelve farms, as are the coefficients for pasture capacity. All other coefficients vary according to class farm. (The technical coefficients used are presented in Tables 2.1 and 2.2.)

Model Constraints

Even though the resource availabilities are different for each farm model, the same resources are constraints in all twelve models. Total operating capital is included as a constraint, but due to lack of data, the quantity of operating capital available is set as equal to gross income of last year, less a fraction deducted for consumption. The quantity of borrowed capital that a farmer can get is based on the rules of the Bank of Brazil.[5/] These rules establish a level of 70 percent of the present value of the fixed assets owned by the farmer as the lending limit.

5/ Relatorio Anual do Banco do Brasil, Brasilia, Brazil, 1967.

Table 2.1. Linear Programming Model, Medium Size, Crop Type Farm in Region 1, Sao Paulo, 1966 to 1967.

Resources: Description	Resources: Units	Amount P_o	Cropland Preparation Machinery P_1	Cropland Preparation Draft Animal P_2	Transfer Permanent Labor Period 1 P_3
Cost (-) or Return (+)	NCr$		-145.45	-43.63	
Cropland	Hectares	47.88	1*	1*	
Pasture	Hectares	35.70			
Permanent Labor Period 1	Man-days	1432.03			1*
Permanent Labor Period 2	Man-days	286.41			
Total Labor Period 1	Man-days				-1
Total Labor Period 2	Man-days				
Borrow Capital	NCr$	24385.00			
Operating Capital	NCr$	16641.00	145.45	43.63	
Prepared Cropland (Machinery)	Hectares		-1*		
Prepared Cropland (Draft Animal)	Hectares			-1*	
Corn	Sacks (60 Kg)				
Beans	Sacks (60 Kg)				
Sugar Cane	Tons				
Rice	Sacks (60 Kg)				
Cotton	Arrobas (15 Kg)				

Table 2.1. (cont'd.)

Resources					
Description	Units	Amount P_o	Cropland Preparation Machinery P_1	Cropland Preparation Draft Animal P_2	Transfer Permanent Labor Period 1 P_3
Peanuts	Sacks (25 Kg)				
Soybean	Sacks (60 Kg)				
Milk	Liters				
Swine	Head				
Veal-Calf	Head				

Table 2.1. (cont'd.)

Description	Transfer Permanent Labor Per. 2	Hiring Temporary Labor Per. 1	Hiring Temporary Labor Per. 2	Mechanized Production Activities					
				Corn	Beans	Sugar Cane	Rice	Cotton	Peanuts
Cost (-) or Return (+)		-2.46	-2.46	-52.68	-16.17*	-78.09*	-27.89	-171.89	-79.84
Pasture				.08*	.07*	.19*	.08*	.05*	.09*
Permanent Labor Period 2	1*								
Total Labor Period 1		-1*		16.25*	14.74*	51.49*	26.49*	30.64*	15.23*
Total Labor Period 2	-1*		-1*	12.56*	12.05*	28.96*	20.77*	28.95*	2.87*
Borrow Capital									
Operating Capital		2.46	2.46	52.68	16.17*	78.09*	27.89	171.89	79.84
Prepared Cropland (Machinery)				1*	1*	1*	1*	1*	1*
Prepared Cropland (Draft Animal)									
Corn				48.73					
Beans					-6.63*				
Sugar Cane						-62.06			
Rice							-23.22		
Cotton								-103.96	
Peanuts									-82.64
Soybean									
Milk									
Swine									
Veal-Calf									

Table 2.1. (cont'd.)

Description	Mech-anized Soybean	Non-Mechanized Projection Activities							Pasture Forma-tion
		Corn	Beans	Sugar Cane	Rice	Cotton	Peanuts	Soybean	
Cost (-) or Return (+)	-78.69	-13.03	-21.32*	-81.07*	-32.85	-177.04	-85.03	-78.69	-69.91*
Pasture	.06*	.13*	.15*	.22*	.16*	.13*	.17*	.17*	-1*
Total Labor Period 1	16.57*	22.91*	19.11*	56.41*	34.15*	37.42*	25.10*	23.12*	5.5*
Total Labor Period 2	10.65*	12.6*	12.12*	28.98*	20.83*	29.01*	2.94*	10.74*	.5*
Borrow Capital									
Operating Capital	78.69	13.03	21.32*	81.07*	32.85	177.04	85.03	78.69	69.91*
Prepared Cropland (Machinery)	1*								
Prepared Cropland (Draft Animal)		1*	1*	1*	1*	1*	1*	1*	
Corn		-12.40							
Beans			-6.63*						
Sugar Cane				-62.06					
Rice					-23.22				
Cotton						-103.96			
Peanuts							-82.64		
Soybeans	-26.34							-26.34	
Milk									
Swine									
Veal-Calf									
Cropland									

Table 2.1. (cont'd.)

Description	Milk	Swine	Rent Pasture	Borrow Capital	Corn Buying	Selling Activities			
						Corn	Beans	Sugar Cane	Rice
Cost (-) or Return (+)	-15.80	- 29.30	14.50	-1.18*	-5.40*	4.86	20.00*	9.08	17.00
Pasture	1.2*	.083*	1*						
Total Labor Period 1	11*	3.33*							
Total Labor Period 2	2*	.67*							
Borrow Capital				1*					
Operating Capital	15.80	29.30		-1*	5.40				
Corn		5.5*			-1*	1*			
Beans							1*		
Sugar Cane								1*	
Rice									1*
Cotton									
Peanuts									
Soybean									
Milk	-811.74								
Swine		-1*							
Veal-Calf	- .7*								

Table 2.1. (cont'd.)

Description	Selling Activities					
	Cotton	Peanuts	Soybean	Milk	Swine	Veal-Calf
Cost (-) or Return (+)	5.37	5.30*	10.50	.183	71.67	120.00
Cotton	1*					
Peanuts		1*				
Soybean			1*			
Milk				1*		
Swine					1*	
Veal-Calf						1*

* These parameters are the same for the twelve representative farms.

Table 2.2. Resource Amounts, Costs and Returns, and Crop Yields for the Linear Programming Models, Study Area, Sao Paulo, 1966 to 1967 Crop Year.

Region	Farm Type	Farm Size	Cropland (Hectares)	Pasture (Hectares)	Permanent Labor Per. 1 Man-Days	Permanent Labor Per. 2 Man-Days	Operating Capital NCr$	Borrow Capital NCr$	Cost per Hectare Cropland Preparation: Machinery NCr$	Cost per Hectare Cropland Preparation: Animal NCr$
1	Crop	Small	27.15	10.23	799.60	159.92	7639.81	7877.06	150.47	43.63
1	Crop	Medium	47.88	35.70	1432.03	286.41	16641.00	24385.00	145.45	43.63
1	Crop	Large	115.96	139.67	1045.13	209.03	38799.85	41049.00	78.46	30.70
1	Crop	Extra Large	280.32	534.84	5379.58	1075.92	104846.25	130692.00	82.60	30.70
2	Crop	Small	11.63	18.81	845.00	169.00	3444.92	5280.54	104.44	50.42
2	Crop	Large	90.73	166.57	2024.00	404.80	30397.98	45000.00	80.30	64.05
2	Crop	Extra Large	111.32	808.28	3180.00	636.00	64234.54	135222.50	144.90	64.05
1	Livestock	Small	24.33	36.53	1002.19	200.44	10110.72	17173.13	132.02	42.85
1	Livestock	Large	44.53	112.77	1551.00	310.20	8521.38	42219.10	198.48	17.90
1	Livestock	Extra Large	12.10	1195.48	821.25	164.25	10663.20	119406.00	82.60	6.77
2	Livestock	Small	9.38	36.45	590.37	118.08	7656.61	14987.88	163.00	62.80
2	Livestock	Large	31.32	196.79	802.65	106.53	13978.24	50858.40	94.09	64.05

Table 2.2. (cont'd.)

Region	Farm Type	Farm Size	Cost per Day: Hiring Temporary Labor Per. 1 NCr$	Cost per Day: Hiring Temporary Labor Per. 2 NCr$	Cost per Hectare: Mechanized Corn NCr$	Mechanized Rice NCr$	Mechanized Cotton NCr$	Mechanized Peanuts NCr$	Mechanized Soybeans NCr$	Non-Mechanized Corn NCr$	Non-Mechanized Rice NCr$
1	Crop	Small	2.33	2.33	45.61	77.00	105.69	99.53	71.60	60.63	31.42
1	Crop	Medium	2.46	2.46	52.68	27.89	171.89	79.84	78.69	13.03	32.85
1	Crop	Large	2.31	2.31	57.97	38.82	126.81	106.42	71.60	50.32	38.95
1	Crop	Extra Large	2.92	2.92	46.48	19.03	151.23	99.53	71.60	29.67	23.99
2	Crop	Small	2.50	2.50	108.74	28.75	148.76	92.19	49.33	53.75	43.79
2	Crop	Large	2.33	2.33	61.06	41.87	148.76	79.84	121.27	108.36	71.17
2	Crop	Extra Large	2.40	2.40	61.06	10.00	148.76	79.84	121.27	108.36	15.00
1	Livestock	Small	2.55	2.55	80.76	39.33	105.69	99.53	71.60	79.92	50.00
1	Livestock	Large	2.71	2.71	61.51	41.15	126.81	106.42	71.60	55.11	38.63
1	Livestock	Extra Large	2.92	2.92	24.68	19.03	151.23	99.53	71.60	29.67	23.97
2	Livestock	Small	2.10	2.10	58.55	40.26	148.76	92.19	44.20	75.84	51.07
2	Livestock	Large	2.00	2.00	60.00	25.77	149.82	111.87	121.27	63.19	30.73

Table 2.2. (cont'd.)

	Farm		Cost per Hectare Non-Mechanized			Cost per Head		Yields Mechanized			
Region	Type	Size	Cotton NCr$	Peanuts NCr$	Soy-beans NCr$	Dairy NCr$	Swine NCr$	Corn Sacks[a]	Sugar Cane Tons	Rice Sacks[a]	Cotton Arrobas[b]
1	Crop	Small	110.84	104.72	78.69	26.03	52.38	29.45	62.06	21.52	52.59
1	Crop	Medium	177.04	85.03	78.69	15.80	29.30	48.73	62.06	23.22	103.96
1	Crop	Large	131.96	111.61	78.69	20.47	34.42	42.78	68.27	26.48	107.11
1	Crop	Extra Large	156.38	104.72	78.69	11.79	40.62	43.57	49.73	17.87	82.64
2	Crop	Small	153.91	97.38	56.42	1.50	39.68	33.15	62.06	12.60	95.39
2	Crop	Large	153.91	85.03	128.36	7.89	42.73	42.56	62.06	20.87	95.39
2	Crop	Extra Large	153.91	85.03	128.36	10.42	42.73	42.56	68.02	28.93	95.37
1	Live-stock	Small	110.84	104.72	78.69	17.75	41.26	38.22	62.06	10.79	52.59
1	Live-stock	Large	131.61	111.61	78.69	13.25	34.99	47.53	68.27	16.53	107.11
1	Live-stock	Extra Large	156.38	104.72	78.69	18.92	40.62	43.57	49.72	17.87	82.64
2	Live stock	Small	92.19	97.38	51.27	22.62	54.03	24.83	62.06	24.43	95.39
2	Live-stock	Large	154.97	117.06	128.36	27.20	47.54	31.57	62.06	26.86	136.36

Table 2.2. (cont'd.)

Region	Farm Type	Farm Size	Yields: Mechanized: Peanuts sacks[c]	Yields: Mechanized: Soybeans sacks[a]	Yields: Non-Mechanized: Corn sacks[a]	Yields: Non-Mechanized: Sugar Cane tons	Yields: Non-Mechanized: Rice sacks[a]	Yields: Non-Mechanized: Cotton Arrobas[b]	Yields: Non-Mechanized: Peanuts sacks[c]	Yields: Non-Mechanized: Soybeans sacks[a]	Milk Per Cow per year liters
1	Crop	Small	60.61	26.34	33.74	62.06	21.17	52.59	60.61	26.34	444.38
1	Crop	Medium	82.64	26.34	12.40	62.06	23.22	103.96	82.64	26.34	811.74
1	Crop	Large	121.21	26.34	25.83	68.27	8.81	107.11	121.21	26.34	615.17
1	Crop	Extra Large	49.59	26.34	33.74	49.73	17.87	82.64	49.59	26.34	292.40
2	Crop	Small	89.53	19.09	26.81	62.06	22.87	95.39	89.53	19.09	498.49
2	Crop	Large	58.93	28.93	52.90	62.06	29.90	95.39	58.93	28.93	725.25
2	Crop	Extra Large	58.93	28.93	52.90	68.02	28.93	95.39	58.93	28.93	661.18
1	Livestock	Small	60.61	26.34	34.49	62.06	12.71	52.59	60.61	26.34	629.57
1	Livestock	Large	121.21	26.34	37.71	68.27	20.27	107.11	121.21	26.34	800.30
1	Livestock	Extra Large	49.59	26.34	33.74	49.73	17.87	82.64	49.59	26.34	258.00
2	Livestock	Small	89.53	30.99	35.81	62.06	35.12	95.39	89.53	30.99	954.12
2	Livestock	Large	123.97	28.93	31.57	62.06	26.86	131.36	123.97	28.93	573.02

Table 2.2. (cont'd.)

	Farm		Return Per Unit Rented or Sold								
Region	Type	Size	Rent-Out Pasture NCr$	Corn NCr$	Sugar Cane NCr$	Rice NCr$	Cotton NCr$	Soybeans NCr$	Milk NCr$	Swine NCr$	Veal-Calf NCr$
1	Crop	Small	28.00	4.98	9.08	18.41	5.54	10.50	.175	60.56	104.00
1	Crop	Medium	14.50	4.86	9.08	17.00	5.37	10.50	.183	71.67	120.00
1	Crop	Large	20.91	4.88	8.93	19.31	5.40	10.50	.163	72.50	98.00
1	Crop	Extra Large	20.91	5.49	9.00	20.33	5.40	10.50	.19	70.00	96.25
2	Crop	Small	28.00	4.94	9.20	18.25	5.35	9.60	.198	72.22	93.33
2	Crop	Large	28.00	5.18	9.20	18.25	5.35	9.90	.189	90.00	93.33
2	Crop	Extra Large	28.00	5.18	8.88	20.00	5.35	9.90	.145	90.00	150.00
1	Livestock	Small	28.00	4.89	9.08	18.88	5.40	10.50	.19	72.50	80.00
1	Livestock	Large	20.91	4.83	9.60	19.80	5.40	10.50	.15	60.00	76.67
1	Livestock	Extra Large	20.91	5.49	9.00	20.33	5.40	10.50	.17	70.00	80.00
2	Livestock	Small	28.00	4.94	9.20	17.58	5.35	12.00	.21	70.00	70.00
2	Livestock	Large	28.00	4.60	9.20	13.33	5.40	9.90	.179	82.50	100.00

a/ 1 sack = 60 Kilograms
b/ 1 Arroba = 15 Kilograms
c/ 1 sack = 25 Kilograms

The resource constraints are:

1. Hectares of cropland.
2. Hectares of pasture.
3. Man-days of permanent labor from July to April.
4. Man-days of permanent labor from May to June.
5. Total operating capital available annually in terms of new cruzeiros.
6. Total borrowed capital that can be obtained annually in terms of new cruzeiros.

The inventory balancing constraints are:

7. Hectares of cropland prepared by draft animals for planting.
8. Hectares of cropland prepared by tractor for planting.
9. Man-days of labor available for production activities from July to April.
10. Man-days of labor available for production activities from May to June.
11. Sacks (60 Kilograms) of ear corn.
12. Sacks (60 Kilograms) of edible beans.
13. Tons of sugar cane.
14. Sacks (60 Kilograms) of rice.
15. Arrobas (15 kilograms) of cotton.
16. Sacks (25 kilograms) of peanuts.
17. Sacks (60 kilograms) of soybeans
18. Milk in liters

19. Hogs
20. Veal calves

Model Vectors

The models are basically the same, except for the coefficients, constraints and yields, which vary from model to model.

The general activities are:

1. Cropland preparation by draft animals.
2. Cropland preparation by tractor.
3. Transferring permanent labor to product activities (from July to April).
4. Transferring permanent labor to product activities (from May to June).
5. Hiring temporary labor from July to April.
6. Hiring temporary labor from May to June.

The crop production activities are:

7. Corn with machinery.
8. Corn with animals.
9. Edible beans with machinery.
10. Edible beans with animals.
11. Sugar cane with machinery.
12. Sugar cane with animals.
13. Rice with machinery.
14. Rice with animals.
15. Cotton with machinery.
16. Cotton with animals.

17. Peanuts with machinery.

18. Peanuts with animals.

19. Soybeans with machinery.

20. Soybeans with animals.

The livestock production activities are:

21. Pasture formation.

22. Dairy.

23. Swine

The borrowing - renting activities are:

24. Rent out pasture.

25. Borrow capital

The buying activities are:

26. Corn

The selling activities are:

27. Corn.

28. Edible beans.

29. Sugar cane.

30. Rice.

31. Cotton.

32. Peanuts.

33. Soybeans.

34. Milk.

35. Swine.

36. Veal calves.

The Structure of the Empirical Models

This section describes the operation of the activities incorporated into the model.

The Cropland Preparation Activity

This activity could be done either by draft animals or machinery (tractor). In both cases it takes one hectare of cropland and contributes one hectare of prepared land for planting. The cost of this activity was computed using depreciation, repairs, interest, taxes and insurance for the equipment used. The operating capital required is equal to the cost associated with the activity.

The Activity of Transferring Permanent Labor

This activity is divided into two periods: one from July to April and the other from May to June (harvesting period). For both periods there is no cost associated with this activity, hence no operating capital is needed. This activity simply takes one man-day of the permanent labor supply and employs it in the production activities.

The Activity of Hiring Temporary Labor

This activity was also split into two periods as was done for the permanent labor activity above. This activity contributes one man-day of temporary labor to be employed in the production activities, at a specified cost. The operating capital required is equal to the cost attached to the activity and there is no restriction on the quantity of temporary labor available.

The Crop Production Activities

All these activities are divided in two sub-activities, depending on whether they are produced using draft animals or machinery. Each of these activities use one hectare of prepared land (by draft animals or machinery depending on the case) for planting, and producing corn, edible beans, sugar cane, rice, cotton, peanuts, or soybeans, and pasture land that is used for the draft animals. Labor requirements for planting, cultivating and harvesting are attached to each activity. The variable costs included in each activity are mainly seed, fertilizer, and pesticide expenses. The amount needed of operating capital is equal to the costs attached to each activity.

The Pasture Formation Activity

This activity uses one hectare of cropland and labor of both periods; it contributes one hectare of pasture land. The costs included in this activity are for seed and fertilizer. The operating capital needed is equivalent to the formation cost of this activity.

The Dairy Production Activity

This activity uses pasture, permanent labor, and operating capital to produce milk and veal calves. The costs included in this activity are feed (other than pasture) and medical expenses. In this cost is reflected the value of the dairy cows after four years of milk production.

The cost to buy a calf and the cost to raise the calf to "cow age" are depreciated by four in the formula:6/

Value of cow when sold - (cost of calf plus cost of raising calf to cow)

The Swine Activity

This activity uses permanent labor and corn for feed and contributes market hogs. Variable cost and operating capital include the cost to buy a "baby pig," medical, and feed expenses except for the cost of corn.

The Rented Pasture Activity

This activity gives a return and uses one hectare of pasture. Neither labor nor operating capital are required.

The Borrowing Capital Activity

This activity has a interest cost of 18 percent of the amount borrowed and contributes to the total operating capital.

The Corn Buying Activity

This activity contributes one sack (60 kilograms) of corn and has a cost attached to it equal to the market price of corn in the region. The operating capital required is equal to the cost.

The Selling Activity

These activities each contribute to the farm income an amount equal to the price of one unit of the product and take one unit of this product to be sold.

6/ Depreciated by four because it is assumed that a cow has a production life of four years.

CHAPTER III

THE OPTIMAL FARM PLANS

The purpose of this chapter is to report the results of the linear programming and sensitivity analysis of the optimal organization for the twelve farms synthesized. (Comparisons between the results obtained and the existing farm organization will be made in the next chapter.)

The Small Size Crop Farm in Region 1

The optimal farm organization for this class of farm, given the model specified, is the following:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	27.15
Permanent labor period 1 (man-days)	799.60
Permanent labor period 2 (man-days)	159.92
Temporary labor hired period 1 (man-days)	491.95
Temporary labor hired period 2 (man-days)	530.53
Production Activities	
Non-mechanized rice (hectares)	12.85
Non-mechanized sugar-cane (hectares)	14.30
Milk cows (head)	4.19[1/]

1/ These fractional units which result from the divisibility assumption do not greatly alter the results in this study.

Selling Activities

Rice (sacks - 60 Kg)	272.06
Sugar cane (tons)	887.38
Milk (liters)	1861.98
Veal - Calf (head)	2.93[1/]

For this specific type and size of farm in this particular region, the income over variable costs is NCr$8457.95[2/]. This amount of money represents the returns to the landowner's land, labor, capital, and management, plus the return to permanent labor.[3/] In this plan the amount of operating capital used is Ncr$5239.00.

Sensitivity Analysis of the Optimal Plan

Sensitivity analysis refers to the study of the effect of changes in the parameters (costs and returns of activities, resource availabilities, and technical coefficients) on the above optimal plan of the model.

Changes in the Costs and Returns of Activities

The penalty costs are used to discover the effect of a change in the cost or return of an activity which is not present in the optimal plan. The penalty cost indicates the

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1/ These fractional units which result from the divisibility assumption do not greatly alter the results in this study.

2/ The rate of exchange at the time of the study was NCr$2.70/US$.

3/ Permanent labor was treated as a fixed resource because of the high costs of dismissing such labor under prevailing lows in Brazil.

amount by which the returns of an activity not included in the optimal plan must increase (or the cost decrease), to bring this activity into the optimal plan without any loss in profit.

The magnitude of the penalty cost of the solution indicates the sensitivity of the optimal farm plan with regard to changes in the costs or returns of the activities not included in the optimal organization (Table 3.1). For example, the cost to produce one hectare of non-mechanized peanuts must decrease by NCr$22,54 or the return per sack of peanuts sold must increase by NCr$1.01 before the production and sale of peanuts will become an economically feasible alternative to the optimal farm organization. The cost per sack of corn bought must decrease by NCr$2.65, so that the purchase price equals the selling price before any corn will be bought. Care must be taken in analyzing these penalty costs because the ranges for which they are valid are not given.

The ranges within which the cost or return of an activity in the optimal plan can vary without affecting the optimality of the plan also gives an indication of its sensitivity. In observing the widths of the ranges for this particular farm plan (Table 3.2), it appears rather insensitive to what one would expect to be normal changes in the costs and returns of most activities in the agricultural plan, but rather sensitive to the return from selling

Table 3.1. Penalty Cost of Activities Not in the Optimal Plan: Small Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Mechanized cropland preparation (hectares)	128.67
Mechanized Corn (hectares)	194.50
Non-mechanized corn (hectares)	197.22
Mechanized beans (hectares)	159.74
Non-mechanized beans (hectares)	164.12
Mechanized rice (hectares)	50.04
Mechanized cotton (hectares)	234.20
Non-mechanized cotton (hectares)	246.48
Non-mechanized peanuts (hectares)	22.54
Mechanized soybeans (hectares)	94.89
Non-mechanized soybeans (hectares)	101.02
Pasture formation (hectares)	152.63
Swine (head)	58.84
Rent-out pasture (hectares)	31.18
Borrow operating capital (NCr$)	.77
Buy corn (sacks)	2.65
Sell peanuts (sacks)	1.01

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.2. Cost and Return Ranges for Activities in the Optimal Plan: Small Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (lower)	(Upper)
Non-mechanized cropland preparation (hectares)	-43.63	-136.94	infinity
Permanent labor period 1 (man-days)	-0-	- 3.29	infinity
Permanent labor period 2 (man-days)	-0-	- 3.29	Infinity
Temporary labor hired period 1 (man-days)	- 2.33	- 4.57	1.83
Temporary labor hired period 2 (man-days)	- 2.33	- 5.79	1.59
Non-mechanized rice (hectares)	-31.42	- 66.47	17.13
Non-mechanized sugar cane (hectares)	-81.07	-101.60	-24.94
Milk cows (head)	-26.03	- 62.57	136.50
Sell rice (sacks)	18.41	16.75	20.70
Sell sugar cane (tons)	9.08	8.30	10.00
Sell milk (liters)	.175	.093	.54
Sell veal-calf (head)	104.00	51.80	336.18

a/ The negative numbers are costs and positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

rice and sugar cane. Relatively small changes in these latter will change the farm plan.

As an example of how this analysis proceeds, in this model the return from the sale of one liter of milk, as specified in the model, is NCr$.175. This return can vary between NCr$.093 and NCr$.54, other things being constant, without requiring any change in the optimal plan. Notice that, as expected, the optimal plan is more sensitive to a decline in the returns than to an increase in them.

It is interesting to observe how changes in selected costs and returns in the optimal plan would alter the farm organization. For example, if permanent labor in either period has an opportunity cost of NCr$3.29, the amount of this labor used will be reduced and the farm will be a less intensive labor user.[4/] Now, if the cost of hiring labor in period 2 increases up to a level as NCr$5.79, permanent labor will substitute for temporary labor in this period, and non-mechanized peanuts, which requires less labor in period 2, will substitute for rice or sugar cane.

Pasture rented out will substitute for dairy production if the cost to raise a cow increases to NCr$62.57, or if the return from selling milk drops to NCr$.093. If the cost of producing sugar cane increases from its original level of NCr$81.07 to NCr$101.60 non-mechanized peanuts will substitute for sugar cane.

4/ Abstracting from the costs of dismissing permanent labor.

Changes in the Resources Availability

The resource availability ranges denote that the optimal farm organization is fairly sensitive with respect to changes in the quantity of resources available to the farm firm (Table 3.3). An increase or a decrease in each resource, with the exception of borrowed operating capital, will change the optimum plan. An increase in cropland or pasture land would change the optimum plan, as would decreases in permanent labor in either period and a decrease in operating capital. The range on both cropland and operating capital is fairly narrow. Borrowed operating capital, which did not enter the solution, is the only resource for which no restriction was imposed, and for which the range was wide.

The marginal value product (shadow price) of a resource is valid within the limits of the resource ranges. Hence, this class of farm could rent out up to 4.827 hectares of cropland (27.15 minus 22.323), at NCr$93.32 per hectare without lowering profits. On the other hand, the acquisition of more cropland would affect the optimality of this plan.

If the supply of permanent labor in period 2 increases up to 791 man-days, at an opportunity cost of NCr$3.29 per day, this class of farm will not hire any temporary labor in this period. If the amount of operating capital goes below the level specified in the model (NCr$5239.00), mechanized sugar cane will substitute for non-mechanized sugar cane.

Table 3.3. Marginal Value Product and Resource Ranges for the Optimal Plan: Small Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a] (Lower)	(Upper)
Cropland (hectares)	27.15	93.32	22.32	27.15
Pasture (hectares)	10.23	59.19	5.32	10.23
Permanent Labor Period 1 (man-days)	799.60	3.29	799.60	1448.72
Permanent Labor Period 2 (man-days)	159.92	3.29	159.92	791.03
Borrow Operating Capital (NCr$)	7877.06	-0-	-0-	infinity
Operating Capital (NCr$)	5239.00	4.13	6751.45	5239.00

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

The interest rate which this category of farms can afford to pay for additional operating capital can be derived from the marginal value product of operating capital. If this small farm has less than NCr$5239.00 of operating capital available, it can afford to pay an annual interest rate for additional operating capital of up to 63 percent, minus any costs not accounted for in the model.

Changes in Technical Coefficients

The effect of changes in crop yields on the optimal farm organization is also studied. The lowest feasible yields per hectare represent the yields of crop production activity not in the optimal plan, which must be obtained, ceteris paribus, before one hectare of this activity can be substituted for one of those already in the plan with no resulting decline in profits (Table 3.4).

For example, suppose fertilization increased non-mechanized corn yields enough in excess of 73.34 sacks per hectare to pay the fertilizer cost per hectare, then the inclusion of this activity would be feasible.

The results indicate that, with two exceptions, the optimal plan is rather insensitive with respect to changes in yields. Relatively small increases in the yields of mechanized rice and non-mechanized peanuts would change the optimum plan.

Summary

The optimal plan for this representative farm consists of non-mechanized rice and non-mechanized sugar cane production and a dairy enterprise. Temporary labor is employed, but no operating capital is borrowed.

The results of the sensitivity analysis are rather mixed. The plan is rather sensitive to changes in returns from rice and sugar cane, to the endowment of resources, and to the yields of mechanized rice and non-mechanized peanuts. It is rather insensitive to changes in the other parameters.

Table 3.4. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Small Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yields/Hectare in the Model	Lowest Feasible Yields/Hectare[a]
Mechanized		
Corn (sacks-60 Kg)	29.45	68.51
Beans (sacks-60 Kg)	6.63	14.62
Rice (sacks-60Kg)	21.52	24.24
Cotton (<u>arrobas</u>-15 Kg)	52.59	94.86
Soybeans (sacks-60 Kg)	26.34	35.38
Non-Mechanized		
Corn (sacks-60 Kg)	33.74	73.34
Beans (sacks-60 Kg)	6.63	14.84
Cotton (<u>arrobas</u>-15 Kg)	52.59	97.08
Peanuts (sacks-25 Kg)	60.61	64.69
Soybeans (sacks-60 Kg)	26.34	35.96

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

The Medium Size Crop Farm in Region 1

The most profitable farm plan for this class of farm, given the model specified, is as follows:

General Activities	Production Level
Non-mechanized cropland preparation (hectares	47.88
Permanent labor period 1 (man-days)	1432.03
Permanent labor period 2 (man-days)	286.41
Temporary labor hired period 1 (man-days)	140.93
Production Activities	
Non-mechanized peanuts (hectares)	44.04
Non-mechanized sugar cane (hectares)	3.84
Milk cows (head)	22.81
Selling Activities	
Peanuts (sacks-25 Kg)	3639.49
Sugar cane (tons)	238.38
Milk (liters)	18513.16
Veal-calf (head)	15.96

For this optimal farm plan the income over variable costs is NCr$19905.19, and the amount of operating capital used is NCr$6852.25.

Sensitivity Analysis of the Optimal Plan

Penalty costs of activities not in the optimal plan are presented in Table 3.5. For this class of farm, it appears that a substantial change must occur in the cost

Table 3.5. Penalty Costs of Activities Not in the Optimal Plan: Medium Size Crop Farm in Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Mechanized cropland preparation (hectares)	59.81
Temporary labor hired period 1 (man-days)	.74
Mechanized corn (hectares)	165.28
Non-mechanized corn (hectares)	304.09
Mechanized beans (hectares)	220.57
Non-mechanized beans (hectares)	207.00
Mechanized sugar cane (hectares	22.23
Mechanized rice (hectares)	48.17
Non-mechanized rice (hectares)	42.49
Mechanized cotton (hectares)	7.66
Mechanized soybean (hectares)	165.17
Non-mechanized soybean (hectares)	163.60
Pasture formation (hectares)	145.24
Swine (head)	9.55
Rent-out pasture (hectares)	140.71
Borrow operating capital (NCr$)	1.18
Sell corn (sacks-60 Kg)	.54
Sell cotton (arrobas-15 Kg)	.39

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

or return of a production activity not in the optimal farm organization before the optimality of this farm plan is affected.

The cost and return ranges for activities in the optimal plan are presented in Table 3.6. Once again the results are rather mixed. Small changes in the return to peanuts and sugar cane would require changes in the optimum farm plan. However, the ranges on the other activities are reasonably wide.

Examples of changes required are instructive. When the cost per day of temporary labor is NCr$1.83, rather than NCr$2.46, temporary labor is employed in period 2 and more hectares of sugar cane will be produced. On the other hand, if the cost per day of hiring temporary labor increases above NCr$3.90, there will be a surplus of labor in period 2, since no temporary labor will be employed in period 1, and the farm organization becomes less labor intensive. If permanent labor in either period has an opportunity cost of NCr$2.56 per day, rather than zero as specified in the model, again the farm organization will be less labor intensive.

Non-mechanized sugar cane will substitute for non-mechanized peanuts if the cost of production of peanuts increases to a level of NCr$104.34 per hectare. However, if the cost of production of non-mechanized sugar cane increases to NCr$103.33 per hectare, mechanized sugar cane

Table 3.6. Cost and Return Ranges for Activities in the Optimal Plan: Medium Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Range of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	- 43.63	-103.44	infinity
Permanent labor period 1 (man-days)	-0-	- 2.46	infinity
Permanent labor period 2 (man-days)	-0-	- 1.72	infinity
Temporary labor hired period 1 (man-days)	- 2.46	- 3.90	- 1.83
Non-mechanized peanuts (hectares)	- 85.03	-104.34	- 77.37
Non-mechanized sugar cane (hectares)	- 81.07	-103.33	- 61.76
Milk cows (head)	- 15.80	-155.66	133.28
Sell peanuts (sacks-25 Kg)	5.30	5.07	5.84
Sell sugar cane (tons)	9.08	8.43	9.39
Sell milk (liters)	.183	.011	.37
Sell veal-calf (head)	120.00	- 79.80	332.97

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity canvary without requiring a change in the set of activities comprising the optimal farm plan.

will substitute for non-mechanized sugar cane. Swine will substitute for dairy cows when the cost to raise dairy cows increases to NCr$155.66 or when the returns from selling milk decreases to NCr$.011 per liter.

This optimal farm organization seems to be less sensitive to resource availabilities than was the previous one (Table 3.7). The existing resource endowment is not a limit in any case, and some adjustments can be made in both directions for every resource. In some cases, these adjustments can be fairly large.

Less temporary labor will be employed either when the supply of cropland decreases to 40.97 hectares or when the amount of pasture available is only 16.07 hectares instead of 35.70 hectares. For the latter situation, less dairy cows will be raised and more permanent labor will be available for crop production. If the supply of permanent labor in period 2 decreases to 186.71 man-days, less non-mechanized sugar cane will be produced.

If this class of farm has more than NCr$6852.25 of operating capital available, the acquisition of more operating capital at any positive interest rate would not be profitable.

Table 3.7. Marginal Value Product and Resource Ranges for the Optimal Farm Plan: Medium Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a/] (Lower)	(Upper)
Cropland (hectares)	47.88	216.15	40.97	82.84
Pasture (hectares)	35.70	155.21	16.09	95.52
Permanent labor Period 1 (man-days)	1432.03	2.46	-0-	1572.96
Permanent labor Period 2 (man-days)	286.41	1.72	186.71	1429.55
Borrow Operating Capital (NCr$)	24835.00	-0-	-0-	infinity
Operating Capital (NCr$)	13041.00	-0-	6852.25	infinity

a/ The ranges represent the limits within which the quanity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.8. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Medium Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a/]
Mechanized		
Corn	48.73	82.74
Beans	8.26	19.29
Sugar Cane	62.06	64.51
Rice	23.22	26.05
Cotton	103.96	105.39
Soybean	26.34	42.07
Non-Mechanized		
Corn	12.40	74.97
Beans	8.26	18.61
Rice	23.22	25.72
Soybean	26.34	41.93

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

The Large Size Crop Farm in Region 1

The optimal farm plan for this class of representative farm, given the model specified, is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectare)	115.96
Permanent labor period 1 (man-days)	1045.13
Permanent labor period 2 (man-days)	209.03
Temporary labor hired period 1 (man-days)	2965.02
Temporary labor hired period 2 (man-days)	331.82
Production Activities	
Non-mechanized peanuts (hectares)	115.96
Milk cows (head)	99.96
Selling Activities	
Peanuts (sacks-25 Kg)	14055.32
Milk (liters)	61494.28
Veal-calf (head)	69.97

The amount of operating capital used in this optimal farm plan is NCr$26163.97 and the income over variable costs is NCr$65210.25.

Sensitivity Analysis of the Optimal Plan

Penalty costs for activities not in the optimal plan are presented in Table 3.9. In general they tend to be larger than for either of the previous two representative farms. Given the qualification presented earlier, they indicate a rather insensitive solution.

Table 3.9. Penalty Costs of Activities Not in the Optimal Plan: Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Mechanized corn (hectares)	401.12
Non-mechanized corn (hectares)	455.02
Mechanized beans (hectares)	416.78
Non-mechanized beans (hectares)	392.32
Mechanized sugar cane (hectares)	170.04
Non-mechanized sugar cane (hectares)	139.63
Mechanized rice (hectares)	141.57
Non-mechanized rice (hectares)	460.88
Mechanized cotton (hectares)	188.02
Non-mechanized cotton (hectares)	169.10
Mechanized peanuts (hectares)	11.72
Mechanized soybeans (hectares)	360.85
Non-mechanized soybeans (hectares)	346.37
Pasture formation (hectares)	403.69
Swine (head)	9.05
Rent-out pasture (hectare)	77.73
Borrow operating capital (NCr$)	1.18
Sell corn (sacks-60 Kg)	1.22

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

The ranges within which the costs and returns of the activities in the optimal plan can vary, without requiring a change in the optimal plan, are rather wide (Table 3.10). In fact, from this standpoint this representative farm is the most insensitive of the three so far presented. The price of the crop is sensitive only on the downward side.

For this optimal farm organization, if the cost per day of hiring temporary labor in period 2 increases from NCr$2.30 to NCr$48.95, less temporary labor will be hired in this period, and permanent labor will be used in crop production. Hence, less dairy cows will be raised and the pasture left will be rented out. However, if the cost of hiring temporary labor in period 2 goes up from NCr$2.30 to NCr$3.59 per day, mechanized peanuts will substitute for non-mechanized peanuts. Again, mechanized peanuts will replace non-mechanized peanuts when the cost of production per hectare of non-mechanized peanuts is NCr$123.33 rather than NCr$111.61 as specified in the model.

Rent-out pasture will substitute for the dairy enterprise either if the cost to raise a cow increases to NCr$113.75 or if the selling price of milk drops to NCr$.011 per liter. Both of these are rather large adjustments.

The optimal farm plan also appears to be reasonably insensitive over a wide range of resource availability (Table 3.11). The existing endowment of resources imposes no upper or lower limits, and the range in each case is reasonably wide. For this class of farm it is not

Table 3.10. Cost and Return Ranges for Activities in the Optimal Plan: Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	- 30.70	- 42.42	infinity
Permanent labor period 1 (man-days)	-0-	- 2.31	infinity
Permanent labor period 2 (man-days)	-0-	- 2.31	infinity
Temporary labor hired period 1 (man-days)	- 2.31	- 3.59	-0-
Temporary labor hired period 2 (man-days)	- 2.31	- 48.95	-0-
Non-mechanized peanuts (hectares)	-111.61	-123.33	infinity
Milk cows (head)	- 20.47	-113.75	155.29
Sell peanuts (sacks-25Kg)	5.30	4.15	infinity
Sell milk (liters)	.163	.011	.45
Veal-calf (head)	98.00	- 35.26	349.08

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.11. Marginal Value Product and Resource Ranges for the Optimal Farm Plan: Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a/] (Lower)	(Upper)
Cropland (hectares)	115.96	418.56	-0-	155.15
Pasture (hectares)	139.67	98.64	19.71	325.85
Permanent labor period 1 (man-days)	1045.13	2.31	-0-	4010.15
Permanent labor period 2 (man-days)	209.03	2.31	-0-	540.84
Borrow operating capital (NCr$)	41049.00	-0-	-0-	infinity
Operating capital (NCr$)	33999.00	-0-	26163.97	infinity

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

profitable to borrow operating capital at any positive interest rate unless the operating capital available is less than NCr$26163.97.

The lowest feasible crop yields indicate the insensitivity of this optimal farm organization to changes in the crop yields (Table 3.12). A change in the yield of non-mechanized peanuts is the only one which is reasonably small.

In summary, this farm produces only non-mechanized peanuts and dairy. It hires substantial quantities of hired labor, especially in period 1, but does not borrow operating capital. In general, the optimal plan is much more insensitive to changes in the parameters than the previous two plans.

Table 3.12. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a]
Mechanized		
Corn (sacks-60 Kg)	42.28	124.48
Beans (sacks-60 Kg)	8.26	29.10
Sugar cane (tons)	68.27	87.31
Rice (sacks-60 Kg)	26.48	33.82
Cotton (<u>arrobas</u>-15 Kg)	107.11	141.92
Peanuts (sacks-25 Kg)	121.21	123.43
Soybeans (sacks-60 Kg)	26.34	60.70
Non-Mechanized		
Corn (sacks-60 Kg)	25.83	119.07
Beans (sacks-60 Kg)	8.26	27.88
Sugar cane (tons)	68.27	83.91
Rice (sacks-60 Kg)	8.81	32.67
Cotton (<u>arrobas</u>-15 Kg)	107.11	138.43
Soybeans (sacks-60 Kg)	26.34	59.32

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

The Extra Large Size Crop Farm, Region 1

The most profitable farm plan for this class of farm, given the model specified, is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	69.45
Permanent labor period 1 (man-days)	5379.58
Permanent labor period 2 (man-days)	1075.92
Temporary labor hired period 1 (man-days)	1158.19
Production Activities	
Non-mechanized peanuts (hectares)	69.45
Milk cows (head)	435.86
Selling Activities	
Peanuts (sacks-25 Kg)	3444.24
Milk (liters)	127445.66
Veal-calf (head)	305.10

The plan uses NCr$17926.20 of operating capital, and the income over variable costs is NCr$53909.03.

Sensitivity Analysis of the Optimal Plan

The penalty costs indicate that in general, relatively large changes in the costs and returns of the activities not in the optimal farm organization must occur before the optimality of this plan is affected (Table 3.13). However, the penalty costs tend to be smaller than in the previous plan.

The ranges within which the costs and returns of the activities in the optimal plan can vary are reasonably wide.

Table 3.13. Penalty Costs of Activities Not in the Optimal Plan: Extra Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Temporary labor hired period 2 (man-days)	1.30
Mechanized corn (hectares)	114.20
Non-mechanized corn (hectares)	143.70
Mechanized beans (hectares)	206.60
Non-mechanized beans (hectares)	176.90
Mechanized sugar cane (hectares)	338.70
Non-mechanized sugar cane (hectares)	305.70
Mechanized rice (hectares)	20.50
Mechanized cotton (hectares)	346.70
Non-mechanized cotton (hectares)	178.40
Mechanized peanuts (hectares)	13.60
Mechanized soybeans (hectares)	100.40
Non-mechanized soybeans (hectares)	80.40
Pasture formation (hectares)	55.10
Swine (head)	25.70
Rent-out pasture (hectares)	18.00
Borrow capital (NCr$)	1.20
Sell corn (sacks-60 Kg)	.20
Sell rice (sacks-60 Kg)	7.50

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

The exceptions are the returns to peanut sales and downward adjustments in the return to milk. A relatively small increase in the costs of the non-mechanized peanut activity would also change the set which makes up the optimal farm plan. (Table 3.14).

For this class of farm, 210.87 hectares of cropland out of the 280.32 hectares available were left idle in the plan. The limiting resource responsible for the non-use of cropland appears to be labor. For an economic use of the idle cropland more temporary labor is needed and this is not a feasible solution.

Mechanized peanuts will substitute for non-mechanized peanuts when the cost of production goes up to NCr$118.05 per hectare. On the other hand, if the cost of production of non-mechanized peanuts drops to NCr$76.00 per hectare, permanent labor should be transferred from the livestock enterprise to crop production. In this case fewer dairy cows will be raised and the remaining pasture will be rented out. Alternatively, if the cost to raise a cow increases to NCr$31.32 or the selling price of milk drops to NCr$.123 per liter, pasture will be rented out.

In analyzing the ranges over which the available resources can vary, it can be seen that the plan is insensitive to changes in the resource availabilities since relatively large changes are necessary for a change to occur in the optimal plan (Table 3.15). A possible exception is

Table 3.14. Cost and Return Ranges for Activities in the Optimal Plan: Extra Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	-30.70	- 44.03	- 1.99
Permanent labor period 1 (man-days)	-0-	- 2.92	infinity
Permanent labor period 2 (man-days)	-0-	- 16.16	infinity
Temporary labor hired period 1 (man-days)	- 2.92	- 3.82	- 1.45
Non-mechanized peanuts (hectares)	-104.72	-118.05	- 76.01
Milk cows (head)	-11.79	- 31.32	46.30
Sell peanuts (sacks-25 Kg)	5.30	4.95	5.88
Sell milk (liters)	.19	.123	.39
Sell veal-calf (head)	96.25	68.34	179.24

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.15. Marginal Value Product and Resource Ranges for the Optimal Farm Plan: Extra Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a/] (Lower)	(Upper)
Cropland (hectares)	280.32	-0-	69.45	infinity
Pasture (hectares)	534.84	38.93	198.72	645.55
Permanent labor period 1 (man-days)	5379.58	2.92	-0-	6537.77
Permanent labor period 2 (man-days)	1075.92	16.16	945.22	1636.12
Borrow operating capital (NCr$)	130692.00	-0-	-0-	infinity
Operating capital (NCr$)	104246.00	-0-	179.26	infinity

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

with permanent labor in period 2, in which case a relatively small reduction in the amount of this resource would change the optimal plan.

If the supply of permanent labor in period 2 is 945.22 man-days instead of 1075.92, less temporary labor will be hired in period 1, and the farm will be less labor intensive. It is not profitable for this class of farm to acquire any extra operating capital, at any positive interest rate, unless its available operating capital should be less than NCr$17926.20.

The results with the technical coefficients are somewhat mixed. Relatively small changes in the yields of mechanized rice and mechanized peanuts would change the optimal plan. Yield changes in the remaining cases would have to be relatively large to change the plan. (Table 3.16).

In summary, the optimal plan for this large farm involves the production of non-mechanized peanuts and the maintenance of a relatively large dairy herd. A relatively large portion of the cropland is left idle, suggesting that under the conditions imposed on the model, a crop farm of this size should be converted into a dairy farm. No temporary labor is hired in period 2, counter to the usual practice in the region, nor is any operating capital borrowed.

The model is relatively stable with respect to changes in the parameters. Relatively small changes in the price of peanuts, changes in the endowment of permanent labor, and some changes in yields will change the optimal plan.

The Small Size Crop Farm in Region 2

The optimal farm organization for this category of farm, given the model specified, is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	11.63
Permanent labor period 1 (man-days)	573.10
Permanent labor period 2 (man-days)	169.00

Table 3.16. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Extra Large Size Crop Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a]
Mechanized		
Corn	43.57	64.37
Beans	6.63	16.96
Sugar Cane	49.73	87.36
Rice	17.87	18.87
Cotton	82.64	146.84
Peanuts	49.59	52.16
Soybeans	26.34	35.91
Non-Mechanized		
Corn	33.74	59.91
Beans	6.63	15.47
Sugar Cane	49.73	83.70
Cotton	82.64	115.68
Soybeans	26.34	33.99

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

Production Activities	
Non-mechanized peanuts (hectares)	7.52
Non-mechanized sugar cane (hectares)	4.11
Milk cows (head)	13.86
Borrowing Activities	
Operating capital (NCr$)	627.62
Selling Activities	
Peanuts (sacks-25 Kg)	673.02
Sugar cane (tons)	255.24
Milk (liters)	6907.10
Veal-calf (head)	9.70

For this class of farm the income over variable costs is NCr$5774.81. For this particular plan the amount of operating capital used is NCr$1045.00.

Sensitivity Analysis of the Optimal Plan

For this class of farm, substantial changes in the costs and returns of those activities not included in the optimal plan must occur before any change in the optimal organization take place (Table 3.17). In addition, the costs and returns of those activities included in the optimal plan can in general vary over a rather wide range without affecting the optimality of the plan (Table 3.18). The exceptions are the returns to the two crop activities, to which the plan is rather sensitive.

Table 3.17. Penalty Costs of Activities Not in the Optimal Plan: Small Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Temporary labor hired period 1 (man-days)	5.45
Temporary labor hired period 2 (man-days)	.62
Mechanized corn	261.90
Non-mechanized corn	105.38
Mechanized beans	314.02
Non-mechanized beans	217.89
Mechanized sugar cane	107.35
Mechanized rice	273.45
Mechanized cotton	304.39
Non-mechanized cotton	208.22
Mechanized peanuts	96.04
Mechanized soybeans	327.63
Non-mechanized soybeans	239.61
Pasture formation	145.60
Swine	92.71
Rent-out pasture	123.12
Sell corn	6.82
Sell rice	1.11

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.18. Cost and Return Ranges for Activities in the Optimal Plan: Small Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	-50.42	-146.46	infinity
Permanent labor period 1 (man-days)	-0-	- 2.09	.52
Permanent labor period 2 (man-days)	-0-	- 4.83	infinity
Non-mechanized peanuts (hectares)	-97.38	-113.54	27.92
Non-mechanized sugar cane (hectares)	-81.07	-117.90	-64.91
Milk cows (head)	- 1.5	-148.77	147.95
Borrow operating capital (NCr$)	- 1.18	- 1.76	.85
Sell peanuts (sacks-25 Kg)	5.30	5.12	6.70
Sell sugar cane (tons)	9.20	8.61	9.46
Sell milk (liters)	.198	- .097	.498
Sell veal-calf (head)	93.33	117.06	306.84

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

In the optimal plan temporary labor is not hired in either period. Moreover, some permanent labor is left idle in period 1, suggesting that this farm has an excess of permanent labor. On the other hand, if the cost of borrowing operating capital drops from NCr$1.18 to NCr$.84, temporary labor will be hired in period 2.

Non-mechanized rice will substitute for non-mechanized sugar cane if the cost of production of sugar cane increases above NCr$117.90 per hectare. If the cost of borrowing operating capital increases to a level of NCr$1.76, non-mechanized corn will enter the optimal plan.

The resource availability can also vary over a reasonably wide range (Table 3.19). If the amount of cropland increases from 11.63 hectares up to 24.96 hectares, the surplus of permanent labor in period 1 will be used, and if it drops to 7.425 hectares, the amount of borrowed operating capital will decrease.

The number of milk cows will decrease if the hectares of pasture available drops from 18.81 hectares to 2.236 hectares. Between the limits of NCr$0.0 and NCr$1672.61, the producer can afford to borrow operating capital at an interest rate of 18 percent a year.

From the lowest feasible yields for this class of farms, it can be seen that relatively large increases in crop yields are necessary in order for crop activities not

Table 3.19. Marginal Value Product and Resource Ranges for the Optimal Plan: Small Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource (Lower)	Range[a] (Upper)
Cropland (hectare)	11.63	116.71	7.43	24.97
Pasture (hectare)	18.81	125.92	2.24	56.65
Permanent labor period 1 (man-years)	845.00	-0-	573.10	infinity
Permanent labor period 2 (man-years)	169.00	4.83	62.25	342.00
Borrow Operating capital (NCr$)	5280.54	-0-	627.62	infinity
Operating capital (NCr$)	1045.00	1.18	-3607.92	1672.62

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

included in the optimal plan to enter the optimal organization without any loss in profit (Table 3.20).

In summary, this farm produces non-mechanized peanuts and sugar cane and maintains a small dairy herd. It is the first farm analyzed so far which borrows operating capital. On the other hand, it does not hire temporary labor in either period, and in period 1 leaves some permanent labor idle.

The sensitivity analysis reveals a solution that is rather stable to changes in the parameters. Small changes

Table 3.20. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Small Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a]
Mechanized		
Corn (sacks-60 Kg)	33.15	86.17
Beans (sacks-60 Kg)	6.63	22.33
Sugar Cane (Tons)	62.06	73.73
Rice (sacks-60 Kg)	12.60	27.58
Cotton (*arrobas*-15 Kg)	95.39	152.29
Peanuts (sacks-25 Kg)	89.53	107.65
Soybean (sacks-60 Kg)	19.09	53.22
Non-Mechanized		
Corn (sacks-60 Kg)	26.81	48.14
Beans (sacks-60 Kg)	6.63	17.53
Cotton (*arrobas*-15 Kg)	95.39	134.31
Soybeans (sacks-60 Kg)	19.09	44.05

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

in the returns to the two crop activities will change the solution. The other parameters can change rather substantially without changing the optimum solution.

The Large Size Crop Farm in Region 2

Given the model specified, the optimal farm organization for this class of farm is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	90.73
Permanent labor period 1 (man-days)	2024.00
Permanent labor period 2 (man-days)	404.80
Temporary labor hired period 1 (man-days)	2468.09
Temporary labor hired period 2 (man-days)	1738.43
Production Activities	
Non-mechanized rice (hectares)	90.73
Milk cows (head)	126.71
Selling Activities	
Rice (sacks-60 Kg)	2718.12
Milk (liters)	91897.64
Veal-calf (head)	88.70

For this class of farm the income over the variable cost is NCr$52183.80 and the operating capital used is NCr$23068.76.

Sensitivity Analysis of the Optimal Plan

The most profitable farm organization for this class of farm appears to be relatively insensitive to changes in the costs and returns of those activities not included in the optimal plan (Table 3.21). Relatively large changes in the costs and returns must occur before the optimality of this farm plan is affected, although the penalty costs are smaller than in the previous case.

The cost and return ranges within which the costs and returns of the activities in the optimal plan can vary are in general quite wide, indicating that the costs and returns can vary over a large range without requiring a change in the optimal plan to achieve the optimum (Table 3.22). An exception is downward adjustments in the price of milk. The range is also somewhat narrower for the price of rice.

For this plan if permanent labor in both periods has an opportunity cost of NCr$2.33 per day the utilization of permanent labor will drop. If the cost of hiring temporary labor in period 1 increases from its initial level of NCr$2.33 to NCr$4.89, mechanized rice will substitute for non-mechanized rice. Swine will substitute for dairy if the cost of raising a head of dairy cattle increases from NCr$7.90 to NCr$35.34 or if the price of selling milk drops from NCr$.189 to NCr$.15.

This farm plan is sensitive to changes in the resources availabilities (Table 3.23). Any change in the amount of cropland or pasture will change the optimum plan, as will any change in the amount of permanent labor in period 2.

Table 3.21. Penalty Costs of Activities Not in the Optimal Plan: Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Mechanized cropland preparation	62.42
Mechanized corn	198.11
Non-mechanized corn	260.54
Mechanized beans	235.00
Non-mechanized beans	307.61
Non-mechanized sugar cane	64.78
Mechanized rice	61.49
Mechanized cotton	63.54
Non-mechanized cotton	141.75
Non-mechanized peanuts	85.47
Mechanized soybean	185.93
Non-mechanized soybean	269.71
Pasture formation	208.59
Swine (head)	1.90
Rent-out pasture	108.85
Borrow operating capital	1.18
Buy corn	.72
Sell peanuts	1.72

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.22. Cost and Return Ranges for Activities in the Optimal Plan: Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation	-64.50	-126.47	infinity
Permanent labor period 1 (man-days)	-0-	- 2.33	infinity
Permanent labor period 2 (man-days)	-0-	- 2.33	infinity
Temporary labor hired period 1 (man-days)	- 2.33	- 4.89	- 1.59
Temporary labor hired period 2 (man-days)	- 2.33	- 6.24	-0-
Non-mechanized rice (hectares)	-71.17	-133.59	infinity
Milk cows (head)	- 7.89	- 35.34	207.89
Sell rice	18.25	16.17	21.20
Sell milk	.189	.15	.49
Sell veal-calf	93.33	54.11	401.58

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.23. Marginal Value Product and Resource Ranges of the Optimal Plan: Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource (Lower)	Range[a] (Upper)
Cropland (hectares)	90.73	261.55	90.73	90.73
Pasture (hectares)	166.57	136.85	166.57	166.57
Permanent labor period 1 (man-days)	2024.00	2.33	423.90	2024.00
Permanent labor period 2 (man-days)	404.8	2.33	404.8	404.8
Borrow operating capital (NCr$)	45000.00	-0-	-0-	infinity
Operating capital (NCr$)	26797.00	-0-	23068.76	infinity

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Increases in the amount of labor in period 1 will also change the optimum plan.

The marginal value product for this class of farm indicates that it is not profitable to borrow operating capital at any positive interest rate, unless the operating capital available is less than NCr$23,068.76.

Again, for this optimal plan, the lowest feasible crop yields indicate that the solution is quite insensitive to those crop yields (Table 3.24). The only exception is mechanized rice. A relatively small increase in the yield of this crop would change the optimal plan.

Table 3.24. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a/]
Mechanized		
Corn	42.56	80.80
Beans	6.63	18.38
Rice	20.87	24.23
Cotton	95.39	107.27
Soybean	28.93	47.71
Non-Mechanized		
Corn	52.90	103.19
Beans	6.63	22.01
Sugar Cane	62.06	69.10
Cotton	95.39	122.88
Peanuts	58.93	75.05
Soybean	28.93	56.17

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

In summary, this farm produces rice and maintains a relatively large dairy herd. It uses temporary labor in both periods, but does not borrow operating capital.

Contrary to the results with the previous farms, this plan is quite sensitive to resource availabilities. It is reasonably stable with respect to changes in the other parameters.

The Extra Large Size Crop Farm in Region 2

The linear programming model specified for this class of farm produced the following optimal farm plan:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	111.32
Permanent labor period 1 (man-days)	3180.00
Permanent labor period 2 (man-days)	636.00
Temporary labor hired period 1 (man-days)	7867.54
Temporary labor hired period 2 (man-days)	3000.24
Production Activities	
Non-mechanized rice (hectares)	111.32
Milk cows (head)	658.72
Selling Activities	
Rice (sacks-60 Kg)	3220.49
Milk (liters)	435535.13
Veal-calf (head)	461.11

The income over variable costs for this class of farm is NCr$155258.53, and the amount of operating capital used is NCr$41,469.80.

Sensitivity Analysis of the Optimal Plan

The penalty costs for this class of farm indicate that in general large changes in the costs and returns of the activities not in the optimal plan must occur before the optimality of this farm plan is affected (Table 3.25). An exception is the sell corn activity. These penalty costs denote that this farm plan is reasonably insensitive to changes in the costs and returns of those activities not included in the optimal farm plan.

The ranges within which the costs and returns of those activities in the optimal farm plan can vary are quite ample. Hence, the costs and returns can vary over a rather large range without affecting the optimal plan (Table 3.26).

If the cost of hiring temporary labor in period 1 moves upwards from its original level of NCr$2.40 to NCr$9.14, mechanized rice will substitute for non-mechanized rice. On the other hand, if the cost of hiring temporary labor in period 2 moves up to NCr$17.64, non-mechanized peanuts will substitute for non-mechanized rice. There will be a decline in the use of permanent labor in both periods if the opportunity cost of this labor should be NCr$2.40 and not zero as specified in the model.

Table 3.25. Penalty Costs of Activities Not in the Optimal Plan: Extra Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a] (NCr$)
Mechanized corn	411.60
Non-mechanized corn	347.30
Mechanized beans	448.40
Non-mechanized beans	394.00
Mechanized sugar cane	186.30
Non-mechanized sugar cane	124.30
Mechanized rice	46.70
Mechanized cotton	279.30
Non-mechanized cotton	230.70
Mechanized peanuts	314.10
Non-mechanized peanuts	273.00
Mechanized soybeans	399.40
Non-mechanized soybeans	356.20
Pasture formation	297.60
Swine (head)	1.90
Rent-out pasture	105.10
Borrow operating capital	1.20
Buy corn	.7

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.26. Cost and Return Ranges for Activities in the Optimal Plan: Extra Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model (NCr$)	Ranges of Cost or Return (Lower)	(Upper)
Non-mechanized cropland preparation	- 64.05	-110.73	infinity
Permanent labor period 1 (man-days)	-0-	- 2.40	infinity
Permanent labor period 2 (man-days)	-0-	- 2.40	infinity
Temporary labor hired period 1	- 2.40	- 9.14	- 1.68
Temporary labor hired period 2	- 2.40	- 17.64	-0-
Non-mechanized rice	- 15.00	- 61.67	infinity
Milk cows (head)	- 10.00	- 36.95	297.82
Sell rice	20.00	15.70	infinity
Sell milk	.145	.104	.61
Sell veal-calf (head)	150.00	111.50	589.74

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

Mechanized rice will substitute for non-mechanized rice as the cost of producing one hectare of non-mechanized rice moves from NCr$15.00 to NCr$61.68. For this class, as was the case for the large class in this same region, fattening hogs will substitute for dairy if the cost to raise a cow increases up NCr$36.95 or if the selling price of milk drops to NCr$.104 per liter.

The resource availability ranges indicate that the optimal plan is relatively insensitive to changes in the resource availability, (Table 3.27). Only decreases in the amount of cropland and increases in the amount of pasture would change the optimal plan.

For this class of farm, the marginal value product indicates that it is not profitable to acquire any operating capital at any positive interest rate, unless the amount available of operating capital is below the lower range of this resource (NCr$41469.80).

The lowest feasible crop yields for this optimal plan also indicate that the optimal farm organization is insensitive to changes in crop yields (Table 3.28). Mechanized rice is the only activity for which a reasonably small change in yields would change the optimal plan.

In summary, this extra large crop farm in region 2 produces non-mechanized rice and maintains a quite large dairy herd. It hires rather substantial quantities of

Table 3.27. Marginal Value Product and Resource Ranges for the Optimal Plan: Extra Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a/] (Lower)	(Upper)
Cropland (hectares)	111.32	346.31	111.32	198.73
Pasture (hectares)	808.28	133.06	27.83	808.28
Permanent labor period 1 (man-days)	3180.00	2.40	-0-	11047.54
Permanent labor period 2 (man-days)	636.00	2.40	-0-	3636.24
Borrow operating capital (NCr$)	135222.50	-0-	-0-	infinity
Operating capital (NCr$)	59434.00	-0-	41469.80	infinity

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.28. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Extra Large Size Crop Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a]
Mechanized		
Corn	42.56	122.01
Beans	6.63	29.05
Sugar Cane	68.02	88.99
Rice	28.93	31.26
Cotton	95.37	147.57
Peanuts	58.93	118.19
Soybean	28.93	69.27
Non-Mechanized		
Corn	52.90	119.94
Beans	6.63	26.33
Sugar Cane	68.02	82.01
Cotton	95.39	138.51
Peanuts	58.93	110.43
Soybean	28.93	64.91

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

temporary labor in both periods, but does not borrow any operating capital. The optimal plan is one of the more insensitive plans encountered.

The Small Size Livestock Farm in Region 1

The optimal farm plan for this class of farm, given the model specified, is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	24.33
Permanent labor period 1 (man-days)	1002.19
Permanent labor period 2 (man-days)	200.44
Temporary labor hired period 1 (man-days)	656.06
Temporary labor hired period 2 (man-days)	556.61
Production Activities	
Non-mechanized sugar cane (hectares)	24.33
Milk cows (head)	25.98
Selling Activities	
Sugar cane (tons)	1509.92
Milk (liters)	16356.96
Veal-calf (head)	18.19

For this specified category of farm the income over variable cost is NCr$11704.41. The amount of operating capital used is NCr$6568.43.

Sensitivity Analysis of the Optimal Plan

With regard to changes in the costs and returns of those activities not included in the optimal plan, the penalty costs indicate that this optimal farm organization is insensitive to those changes (Table 3.29). Selling corn is the one activity which would not impose a substantial penalty cost.

In observing the widths of the costs and returns ranges of the activities in the optimal plan, it appears that the solution is insensitive to what one could expect to be normal changes in those costs and returns (Table 3.30). The most sensitive appears to be the return for sugar cane on the downward side. However, even in this case the change has to be relatively large.

Mechanized cropland preparation substitutes for non-mechanized cropland preparation, and mechanized sugar cane substitutes for non-mechanized sugar cane, when the cost of the non-mechanized activities increases from NCr$42.85 to NCr$93.17 and from NCr$81.07 to NCr$101.23, respectively. These are fairly large changes.

Rent-out pasture will substitute for dairy production if either the cost of production of dairy increases to NCr$108.87 or the selling price of milk drops to NCr$.045. On the other hand, if the selling price of milk increases to a level as NCr$.47, pasture formation will substitute for sugar cane.

Table 3.29. Penalty Costs of Activities Not in the Optimal Plan: Small Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Mechanized cropland preparation	50.32
Mechanized corn	236.83
Non-mechanized corn	239.64
Mechanized beans	239.84
Non-mechanized beans	225.77
Mechanized sugar cane	20.16
Mechanized rice	245.12
Non-mechanized rice	208.69
Mechanized cotton	252.17
Non-mechanized cotton	244.22
Mechanized soybean	151.35
Non-mechanized soybean	147.96
Pasture formation	180.25
Swine	17.29
Rent-out pasture	75.93
Borrow operating capital	1.18
Sell corn	.51
Sell peanuts	1.89

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.30. Cost and Return Ranges for Activities in the Optimal Plan: Small Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	-42.85	- 93.17	infinity
Permanent labor period 1 (man-days)	-0-	- 2.55	infinity
Permanent labor period 2 (man-days)	-0-	- 2.55	infinity
Temporary labor hired period 1 (man-days)	- 2.55	- 6.21	-0-
Temporary labor hired period 2 (man-days)	- 2.55	- 6.96	infinity
Milk cows	-17.75	-108.87	159.55
Sell sugar cane	9.08	7.24	infinity
Sell milk	.19	.045	.47
Sell veal-calf	80.00	- 50.17	333.28

a/ The negative numbers are costs and positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

The utilization of permanent labor in both periods will decrease if permanent labor has an opportunity cost of NCr$2.55. If the cost of hiring temporary labor in period 1 increases from its initial level of NCr$2.55 to NCr$6.21, less cropland will be cultivated. On the other hand, if the cost of hiring temporary labor in period 2 is the one that increases from NCr$2.55 to NCr$6.96, less labor will be hired in this period and non-mechanized peanuts will substitute for non-mechanized sugar cane.

The ranges within which the marginal value products are valid (resource availability ranges) are reasonably wide, denoting the insensitivity of this farm plan to changes in those coefficients (Table 3.31). The closest limit is for cropland, in which case a reasonably small increase in the cropland available would change the optimal plan.

For this class of farm it is not profitable to borrow any operating capital at any positive interest rate within the ranges specified on Table 3.31.

The lowest feasible yields also suggest that the optimal plan (Table 3.32) is relatively insensitive to changes in this parameter. The only exception is mechanized sugar cane, in which case a relatively small change in yields will change the optimal solution.

In summary, this small livestock farm in Region 1 uses its cropland to produce non-mechanized sugar cane and

Table 3.31. Marginal Value Product and Resource Ranges for the Optimal Plan: Small Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a/] (Lower)	(Upper)
Cropland (hectares)	24.33	198.98	12.27	27.77
Pasture (hectares)	36.53	103.93	5.35	63.44
Permanent labor period 1 (man-days)	1002.19	2.55	554.52	1658.25
Permanent labor period 2 (man-days)	200.44	2.55	-0-	757.05
Borrow operating capital (NCr$)	17173.13	-0-	-0-	infinity
Operating capital (NCr$)	7710.00	-0-	6568.43	infinity

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.32. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Small Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a/]
Mechanized		
Corn	38.22	86.65
Beans	6.63	18.62
Sugar Cane	62.06	64.27
Rice	10.79	23.77
Cotton	52.59	99.26
Soybean	26.34	40.75
Non-Mechanized		
Corn	34.49	83.49
Beans	6.63	19.41
Rice	12.71	23.76
Cotton	52.59	97.81
Soybean	26.34	40.43

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

maintains a dairy herd. It hires temporary labor in both periods, but does not borrow operating capital. In general, the solution is relatively insensitive to changes in the parameters.

The Large Size Livestock Farm in Region 1

The most profitable farm plan for this class of farm, given the model specified, is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	44.53
Permanent labor period 1 (man-days)	1551.00
Permanent labor period 2 (man-days)	306.24
Temporary labor hired period 1 (man-days)	530.92
Production Activities	
Non-mechanized peanuts (hectares)	44.53
Milk cows (head)	87.67
Borrowing Activities	
Operating capital (NCr$)	34458.11
Selling Activities	
Peanuts (sacks-25 Kg)	5396.88
Milk (liters)	70160.13
Veal-calf (head)	61.37

The income over variable costs for this farm plan is NCr$31399.60, and the operating capital used is NCr$4921.00

Sensitivity Analysis of the Optimal Plan

From the analysis of the penalty costs, it appears that a substantial change must occur in the costs and returns of the activities not included in the optimal farm plan before its optimality is affected (Table 3.33). This is true of all activities not included in the plan.

The ranges over which the costs and returns of those activities in the optimal farm organization can vary, one at a time, are reasonably large for all except two activities (Table 3.34). A slight decline in the cost of borrowed capital would alter the optimal plan, as would a slight decrease in the price of peanuts.

If permanent labor in period 2 has an opportunity cost of NCr$1.00, mechanized peanuts will substitute for non-mechanized peanuts. If the cost of hiring temporary labor in period 1 goes up from its original level of NCr$2.71 to NCr$7.69, permanent labor will be used in the crop production, and less dairy cows will be raised. The remaining pasture should be rented out. In addition, rent-out pasture will substitute for dairy if the cost of raising a cow increases to NCr$68.00 or if the price of selling milk drops to NCr$.08 per liter. Non-mechanized corn will substitute for non-mechanized peanuts if the cost of producing one hectare of the latter increases to NCr$171.51, or if the selling price of peanuts decreases to NCr$4.81.

Table 3.33. Penalty Costs of Activities Not in the Optimal Plan: Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] NCr$
Mechanized cropland preparation	309.06
Temporary labor hired period 2	5.91
Non-mechanized corn	59.90
Mechanized beans	285.90
Non-mechanized beans	243.66
Mechanized sugar cane	47.04
Mechanized rice	138.44
Mechanized cotton	28.00
Mechanized peanuts	9.65
Mechanized soybeans	305.51
Non-mechanized soybeans	282.38
Pasture formation	318.85
Swine	106.22
Rented-out pasture	45.63
Sell corn	6.84
Sell sugar	1.59
Sell rice	7.37
Sell cotton	1.67

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.34. Cost and Return Ranges for Activities in the Optimal Plan: Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a/] (NCr$)	Ranges of Cost or Return[b/] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	- 17.90	-218.38	infinity
Permanent labor period 1 (man-days)	-0-	- 5.91	infinity
Permanent labor period 2 (man-days)	-0-	- .99	4.19
Temporary labor hired period 1 (man-days)	- 2.71	- 7.69	.82
Non-mechanized peanuts	-111.61	-171.51	- 83.61
Milk cows	- 13.25	- 68.00	313.77
Borrow operating capital	- 1.18	- 1.41	- 1.15
Sell peanuts	5.30	4.81	5.40
Sell milk	.15	.082	.56
Sell veal-calf	76.67	- 1.55	543.84

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

The results are rather mixed with respect to resource availabilities. (Table 3.35). Relatively small increases in either cropland or pasture would change the optimal plan, as would a relatively small reduction in the availability of permanent labor in period 2. Other resource availabilities could move substantially before imposing a change on the optimal plan.

If the supply of cropland decreases, less operating capital will be borrowed. On the other hand, if less pasture is available, permanent labor will be used in crop production and as a result less temporary labor will be hired in period 1.

For this farm plan it is profitable to borrow operating capital at an interest rate of 18 percent a year. If the operating capital available is greater than NCr$ 8366.81, however, it is not profitable to borrow at that price.

The optimum plan is relatively sensitive to changes in yields of crops not in the solution. (Table 3.36) Relatively small changes in the yields of mechanized sugar cane, cotton, and peanuts would change the optimal plan. On the other hand, it should be pointed out that the yields used in this model are relatively high for Brazilian conditions. It may be that even these small changes in yields will be difficult to obtain.

Table 3.35. Marginal Value Product and Resource Ranges for the Optimal Plan: Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a/] (Lower)	(Upper)
Cropland (hectares)	44.53	200.48	26.53	46.02
Pasture (hectares)	112.77	66.54	54.85	115.15
Permanent labor period 1 (man-days)	1551.00	5.91	-0-	2081.92
Permanent labor period 2 (man-days)	310.20	-0-	306.24	infinity
Borrow operating capital (NCr$)	42219.10	-0-	3445.81	infinity
Operating capital (NCr$)	4921.00	11.8	-33852.29	8366.81

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.36. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a/]
Mechanized		
Beans	6.63	20.92
Sugar Cane	68.27	73.17
Rice	16.53	23.52
Cotton	107.11	112.66
Peanuts	121.21	123.03
Soybean	26.34	55.43
Non-Mechanized		
Corn	37.71	50.11
Beans	6.63	18.81
Soybean	26.34	53.23

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

In summary, this large size livestock farm in Region 1 produces non-mechanized peanuts and maintains a herd of dairy cows. It hires temporary labor only in period 1, but borrows substantial amounts of operating capital.

The optimal plan is rather sensitive to changes in the parameters of the model. Changes in resource availability will change the optimum plan, as will changes in some yields. However, in the latter case, these changes in yields may be rather difficult to obtain.

The Extra Large Size Livestock Farm in Region 1

The optimal farm plan for this class of representative farm, given the model specified, is as follows:

General Activities	Production Levels.
Non-mechanized cropland preparation (hectares)	12.10
Permanent labor period 1 (man-days)	821.25
Permanent labor period 2 (man-days)	164.25
Temporary labor hired period 1 (man-days)	190.18
Production Activities	
Non-mechanized peanuts (hectares)	12.10
Milk cows (head)	64.34
Rent-out Activities	
Pasture (hectares)	1116.22

Selling Activities

Peanuts (sacks-25 Kg)	600.04
Milk (liters)	16599.20
Veal-calf (head)	45.04

The income over variable costs for this class of farm is NCr$29,823.48. The amount of operating capital necessary for this particular plan is NCr$3121.60.

Sensitivity Analysis of the Optimal Plan

The analysis of penalty costs indicates that in general relatively large changes in the costs and returns of those activities not included in the optimal plan must occur before the plan is affected (Table 3.37). Exceptions are the temporary labor in period 2 and the sell corn activities.

The cost and return ranges over which the costs and returns of the activities can vary are reasonably wide, with the exception of the price of milk. This indicates that this plan is relatively insensitive to changes in those parameters (Table 3.38).

Mechanized peanuts will substitute for non-mechanized peanuts if the cost of production per hectare of this crop increases from NCr$104.72 to NCr$144.04. Not all of the permanent labor supply in period 1 will be utilized if this labor has an opportunity cost of NCr$2.92. On the other hand, the opportunity cost for permanent labor in period 2

Table 3.37. Penalty Costs of Activities Not in the Optimal Plan: Extra Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Temporary labor hired period 2	1.70
Mechanized corn	98.50
Non-mechanized corn	102.90
Mechanized beans	193.20
Non-mechanized beans	137.80
Mechanized sugar cane	250.60
Non-mechanized sugar cane	193.00
Mechanized rice	46.10
Mechanized cotton	261.20
Non-mechanized cotton	105.90
Mechanized peanuts	39.30
Mechanized soybean	93.20
Non-mechanized soybean	47.00
Pasture formation	110.60
Swine	21.40
Borrow operating capital	1.20
Sell corn	.20
Sell rice	3.20

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.38. Cost and Return Ranges for Activities in the Optimal Plan: Extra Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	- 6.77	- 46.09	infinity
Permanent labor period 1 (man-days)	-0-	- 2.92	infinity
Permanent labor period 2 (man-days)	-0-	- 11.86	infinity
Temporary labor hired period 1	- 2.92	- 3.56	-0-
Non-mechanized peanuts	-104.72	-144.04	infinity
Milk cows	- 18.92	- 25.32	8.03
Rent-out pasture	20.91	-0-	26.24
Sell peanuts	5.30	4.5	infinity
Sell milk	. 17	.145	.274
Sell veal-calf	80.00	70.86	118.49

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

must be NCr$11.86 before the utilization of it is affected. Non-mechanized rice will substitute for non-mechanized peanuts if the cost of hiring temporary labor goes above NCr$3.56.

The resource availability ranges also indicate that this optimal farm organization is rather insensitive to changes in the resource availabilities (Table 3.39). As the amount of pasture available drops from 1195.48 hectares to 79.26 hectares, less pasture will be rented out. If the supply of permanent labor in period 2 decreases from the initial level of 164.25 man-days to 129.67, less temporary labor will be hired in period 1 and the farm will be a less intensive labor user.

For this farm it is not profitable to acquire any operating capital, at any positive interest rate, unless the operating capital is less than NCr$3121.60.

The lowest feasible crop yields for this farm plan denote that reasonable changes in the crop yields must occur before the optimality of this plan is affected (Table 3.40). The two for which the smallest changes are required are mechanized rice and non-mechanized soybeans. However, even these changes are relatively large.

In summary, this extra large livestock farm also produces non-mechanized peanuts and maintains a dairy herd. The interesting thing is that the optimum plan indicates

Table 3.39. Marginal Value Product and Resource Ranges for the Optimal Plan: Extra Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a] (Lower)	(Upper)
Cropland (hectares)	12.10	39.61	-0-	37.08
Pasture (hectares)	1195.48	20.91	79.26	infinity
Permanent labor period 1 (man-days)	821.25	2.92	-0-	1011.43
Permanent labor period 2 (man-days)	164.25	11.86	129.67	271.67
Borrow operating capital (NCr$)	119406.00	-0-	-0-	infinity
Operating capital (NCr$)	5863.00	-0-	3121.60	infinity

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.40. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Extra Large Size Livestock Farm, Region 1, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a]
Mechanized		
Corn	43.57	61.51
Beans	6.63	16.29
Sugar Cane	49.73	77.57
Rice	17.87	20.13
Cotton	82.64	131.01
Peanuts	49.59	57.00
Soybean	26.34	35.21
Non-Mechanized		
Corn	33.74	52.48
Beans	6.63	13.52
Sugar Cane	49.73	71.17
Cotton	82.64	102.25
Soybean	26.34	30.67

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

that a large fraction of the relatively large supply of pasture land should be rented out. The size of the dairy herd is somewhat smaller than in the previous case.

The farm should hire temporary labor only in period 1 and does not borrow any operating capital. The optimum plan is relatively insensitive to changes in the parameters of the model.

The Small Size Livestock Farm in Region 2

The optimal farm organization for this category of farm, given the model specified, is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	9.83
Permanent labor period 1 (man-days)	590.37
Permanent labor period 2 (man-days)	118.08
Temporary labor hired period 1 (man-days)	15.27
Temporary labor hired period 2 (man-days)	107.59
Production Activities	
Non-mechanized rice (hectares)	5.28
Non-mechanized corn (hectares)	4.55
Milk cows (head)	29.18
Selling Activities	
Rice (sacks-60 Kg)	185.42
Corn (sacks-60 Kg)	1629.55
Milk (liters)	27839.40
Veal-calf (head)	20.43

For this optimal farm organization, the income over variable costs is NCr$13329.64, and the operating capital used is NCr$5256.00.

Sensitivity Analysis of the Optimal Plan

The most profitable farm plan for this category of farm appears to be relatively insensitive to what one would consider normal changes in the costs and returns of those activities not included in the optimal farm organization (Table 3.41). The penalty costs are relatively large.

In analyzing the cost and return ranges for those activities in the optimal plan, it can be seen that those costs and returns can vary over a reasonably wide range, indicating that the optimal plan is insensitive to changes in those costs and returns (Table 3.42). The narrowest range is in the sell rice activity and this is on the downward side of the return.

For this optimal farm plan, if permanent labor, in either period, has an opportunity cost of NCr$3.64, the utilization of permanent labor will be lowered, and the farm will be a less intensive labor user. On the other hand, if the cost of hiring temporary labor in period 1 is NCr$7.55, and not NCr$2.10 as specified in the model, less cropland will be cultivated, and the land will be left idle.

Non-mechanized peanuts will substitute for non-mechanized rice when the cost of production of the latter

Table 3.41. Penalty Costs of Activities Not in the Optimal Plan: Small Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Mechanized cropland preparation	146.78
Mechanized corn	134.26
Mechanized beans	336.69
Non-mechanized beans	345.38
Mechanized rice	157.48
Mechanized cotton	305.59
Non-mechanized cotton	323.02
Non-mechanized peanuts	28.79
Mechanized soybean	146.23
Non-mechanized soybean	170.36
Pasture formation	205.45
Swine	76.68
Rent-out pasture	107.67
Borrow operating capital	.45
Buy corn	4.42
Sell Sugar cane	3.50
Sell peanuts	1.09

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.42. Cost and Return Ranges for Activities in the Optimal Plan: Small Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	- 62.80	-209.58	infinity
Permanent labor period 1 (man-days)	-0-	- 3.64	infinity
Permanent labor period 2 (man-days)	-0-	- 3.64	infinity
Temporary labor hired period 1 (man-days)	- 2.10	- 7.55	1.42
Temporary labor hired period 2 (man-days)	- 2.10	- 7.49	1.45
Non-mechanized rice (hectares)	- 51.07	-145.72	439.06
Non-mechanized corn (hectares)	- 75.84	-124.85	- 46.06
Milk cows	- 22.62	-152.06	189.11
Sell rice	17.58	14.88	31.53
Sell corn	4.94	3.57	5.77
Sell milk	.21	.074	.43
Sell veal-calf	70.00	-114.92	872.46

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

increases to NCr$145.72. Rent-out pasture will be the best solution if the cost of raising a cow increases to NCr$162.06, or the selling price of milk drops to NCr$.074 per liter.

This plan is sensitive to changes in resource availabilities. Reductions in both cropland and pasture will change the plan, as will slight increases in both. Increases in permanent labor and in operating capital will also change it. (Table 3.43)

If the supply of cropland drops below the level specified in the model (9.83 hectares), non-mechanized beans will enter the optimal plan. Mechanized sugar cane will enter the optimal plan if the supply of permanent labor in period 1 decreases to 535.09 or if the supply of permanent labor in period 2 decreases to 62.08 man-days.

Unless the operating capital available is less than NCr$513.99, it is not profitable for this class of farm to borrow operating capital at any positive interest rate.

Also for this class of farm the lowest feasible crop yields demonstrate an insensitivity of this optimal farm organization to changes in the crop yields (Table 3.44). The only exception is non-mechanized peanuts, for which a relatively small increase in yields would change the optimal plan.

In summary, the small size livestock farm in Region 2 produces small amounts of non-mechanized rice and corn and

Table 3.43. Marginal Value Product and Resource Ranges for the Optimal Plan: Small Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a] (Lower)	(Upper)
Cropland (hectares)	9.83	198.05	9.83	9.88
Pasture (hectares)	36.45	135.67	36.45	37.81
Permanent labor period 1 (man-days)	590.37	3.64	535.09	590.37
Permanent labor period 2 (man-days)	118.08	3.64	62.80	118.08
Borrow operating capital (NCr$)	14987.88	-0-	-0-	infinity
Operating capital (NCr$)	5256.00	7.34	5139.91	5256.00

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.44. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Small Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a]
Mechanized		
Corn	24.83	296.62
Beans	6.63	23.46
Rice	24.43	33.38
Cotton	95.39	152.50
Soybean	30.99	43.17
Non-Mechanized		
Beans	6.63	23.89
Cotton	95.39	156.00
Peanuts	89.53	94.96
Soybeans	30.99	45.18

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

maintains a small dairy herd. It employs relatively small amounts of temporary labor, but borrows no operating capital. The optimal plan is insensitive to all of the parameters except resource availability. However, it is relatively sensitive to changes in this parameter.

The Large Size Livestock Farm in Region 2

Given the model specified, the optimal farm organization for this class of farm is as follows:

General Activities	Production Levels
Non-mechanized cropland preparation (hectares)	31.32
Permanent labor period 1 (man-days)	802.65
Permanent labor period 2 (man-days)	160.53
Temporary labor hired period 1 (man-days)	1738.58
Temporary labor hired period 2 (man-days)	250.66
Production Activities	
Non-mechanized peanuts (hectares)	31.32
Milk cows (head)	159.55
Borrowing Activities	
Operating capital (NCr$)	36127.39
Selling Activities	
Peanuts (sacks-25 Kg)	3882.74
Milk (liters)	91428.02
Veal-calf (head)	111.69

For this optimal plan, the income over variable costs is NCr$29859.19, and the amount of operating capital used is NCr$10378.00.

Sensitivity Analysis of the Optimal Plan

For this class of farm substantial changes in the costs or returns of the production activities not in the optimal farm organization must occur before the optimal plan will be affected (Table 3.45). The one exception is the return to cotton.

In general, the costs and returns of those activities in the optimal plan can vary over a rather wide range without requiring a change in the optimal farm plan (Table 3.46). However, for temporary labor and the sell milk activity, substantial changes in the costs or returns would change the optimum plan.

If the permanent labor in both periods has an opportunity cost of NCr$4.36, less labor will be supplied, and the farm should operate as a less intensive labor user. If the cost of hiring temporary labor in period 1 increases to NCr$2.77, mechanized peanuts will substitute for non-mechanized peanuts. On the other hand, if the cost of hiring temporary labor in period 2 goes up to NCr$13.50, permanent labor is used in the crop production, less dairy cows will be raised and the pasture remaining should be rented out. Mechanized peanuts will substitute for

Table 3.45. Penalty Costs of Activities Not in the Optimal Plan: Large Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Penalty Cost[a/] (NCr$)
Mechanized cropland preparation (hectares)	7.06
Mechanized corn	184.14
Non-mechanized corn	164.36
Mechanized beans	352.76
Non-mechanized beans	328.69
Mechanized sugar cane	288.97
Non-mechanized sugar cane	260.08
Mechanized rice	237.97
Non-mechanized rice	227.85
Mechanized cotton	46.79
Mechanized soybean	429.47
Non-mechanized soybean	420.64
Pasture formation	263.35
Swine	113.23
Rent-out pasture	19.16
Sell corn	8.26
Sell cotton	1.14

a/ The penalty cost represents the decline in profit incurred as a result of including one unit of the corresponding activity in the optimal farm plan.

Table 3.46. Cost and Return Ranges for Activities in the Optimal Plan: Large Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Activity	Cost or Return in Model[a] (NCr$)	Ranges of Cost or Return[b] (Lower)	(Upper)
Non-mechanized cropland preparation (hectares)	- 64.05	- 71.11	infinity
Permanent labor period 1 (man-days)	-0-	- 4.36	infinity
Permanent labor period 2 (man-days)	-0-	- 4.36	infinity
Temporary labor hired period 1 (man-days)	- 2.00	- 2.77	2.36
Temporary labor hired period 2 (man-days)	- 2.00	- 13.50	2.36
Non-mechanized peanuts	-117.06	-124.12	- 68.48
Milking cows	- 27.20	- 50.19	78.72
Borrow operating capital	- 1.18	- 1.61	- .35
Sell peanuts	5.30	4.24	infinity
Sell milk	.179	.14	.36
Sell veal-calf	100.00	.67	261.32

a/ The negative numbers are costs and the positive numbers represent returns.

b/ The ranges represent the limits within which the cost or return of the activity can vary without requiring a change in the set of activities comprising the optimal farm plan.

non-mechanized peanuts when the cost of production of the later moves from NCr$117.06 to NCr$124.12. If the cost of production of milk increases to NCr$50.19 or the interest rate to borrow operating capital is 61 percent instead of 18 percent, or even if the selling price of milk drops to NCr$.14, the number of dairy cows raised will decrease, and some pasture will be rented out.

The ranges over which the resource availabilities can vary indicates tha t the solution is insensitive to changes in the resource availabilities (Table 3.47). The smallest change would be with cropland, but even it would have to be reduced 50 percent in order to change the plan.

If the supply of cropland decreases from its original level to 16.55 hectares, mechanized peanuts will substitute for non-mechanized peanuts. Less operating capital will be borrowed if the availability of pasture changes from 196.79 hectares to 115.30 hectares.

For this class of farm, it is profitable to borrow capital at an interest rate of 18 percent up to an operating capital availability of NCr$13,990.74.

The lowest feasible crop yields for this optimal plan indicates that this optimal farm organization is relatively insensitive to change in the crop yields (Table 3.48). The only exception is mechanized cotton, for which a relatively small increase in yields would change the optimal plan.

Table 3.47. Marginal Value Product and Resource Ranges for the Optimal Plan: Large Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Resource	Amount Available	MVP NCr$	Resource Range[a] (Lower)	(Upper)
Cropland (hectares)	31.32	131.94	16.56	237.05
Pasture (hectares)	196.79	47.16	115.30	372.29
Permanent labor period 1 (man-days)	802.65	4.36	-0-	2541.23
Permanent labor period 2 (man-days)	160.53	4.36	-0-	411.19
Borrow operating capital (NCr$)	50858.40	-0-	3612.74	infinity
Operating capital (NCr$)	10378.00	11.80	-36867.66	1399074

a/ The ranges represent the limits within which the quantity of the resource can vary without requiring a change in the set of activities comprising the optimal farm plan.

Table 3.48. Lowest Feasible Yields of Crop Production Activities Not in the Optimal Plan: Large Size Livestock Farm, Region 2, Sao Paulo, 1966 to 1967 Crop Year.

Crop Activity	Yield/Hectare in the Model	Lowest Feasible Yield/Hectare[a]
Mechanized		
Corn	31.57	71.60
Beans	6.63	24.26
Sugar Cane	62.06	93.46
Rice	26.86	44.71
Cotton	136.36	145.02
Soybean	28.93	72.30
Non-Mechanized		
Corn	31.57	67.30
Beans	6.63	23.06
Sugar Cane	62.06	90.54
Rice	26.86	43.95
Soybean	28.93	71.41

a/ The lowest feasible yield per hectare represents the yield which must be attained from the corresponding crop activity in order that one unit of this activity could be included in the optimal farm plan without incurring a decline in profit. This is calculated by dividing the penalty cost of the activity by the return per crop unit sold. This quotient then is added to the yield per hectare specified in the model.

In summary, this farm will use its cropland to produce non-mechanized peanuts and maintain a dairy herd. It will hire relatively large amounts of temporary labor and borrow substantial amounts of operating capital. The optimal plan is relatively insensitive to changes in the parameters of the model.

CHAPTER IV

SUMMARY OF FINDINGS, POLICY IMPLICATIONS, AND SUGGESTIONS FOR FUTURE RESEARCH

Summary of Findings

On the assumption that in the short run the basic objectives of the farm firm is to maximize net revenue to the fixed factors, linear programming has been used to determine the optimum combination of resources and enterprises for twelve representative farms in the study area. The representative farms were classified on the basis of region, size as measured by hectares, and whether they tended to be specialized in livestock or crop production.

Basic data for the research were collected in direct interviews with a sample of farm operators in the study area and such secondary data as was necessary. The representative farms were developed to be rather typical of those in the area. Coefficients and resource restrictions used in the analysis were averages from the farms in the sample that were classified in each category.

The programming model was short-run in nature in the sense that certain inputs were fixed. It involved 36 activities and 20 equations and attempted to include the major production activities felt to be viable in the region. The model assumes single valued expectations on the part of the farm operator and assumes that the entrepreneurs have perfect knowledge.

The results of the analysis suggest important reorganizations of the farms in the region. This has important implications not only at the firm level, but also for policy makers working at the macro level. The results can best be summarized by treating separately the various components of the farm organization, and where possible, comparing them with the actual organization of the representative farms.

The Cropping Pattern

As Table 4.1 indicates, the representative farms in the region tend to have a rather diversified cropping pattern. The table is set up so that it shows what proportion of the hectares in each crop is mechanized (use tractor power) and what proportion is not mechanized (use animal power).[1] This will be useful in the analysis below.

1/ This distinction was made in the initial analysis in order to obtain coefficients which would permit our evaluation of the viability of tractor power.

Table 4.1. Percentages of Cropland Used in the Various Crop Production Activities, Actual Farm Organization for Each Size of Farm, Study Area, Sao Paulo, 1966 to 1967 Crop Year.

	Crop Farms							Livestock Farms				
	Region 1				Region 2			Region 1			Region 2	
	Small	Medium	Large	Extra Large	Small	Large	Extra Large	Small	Large	Extra Large	Small	Large
Mechanized												
Corn	18.00	57.34	69.12	50.00	1.26	44.00	-0-	49.00	40.32	-0-	9.30	40.00
Beans	-0-	-0-	-0-	-0-	-0-	-0-	-0-	1.00	-0-	-0-	-0-	-0-
Sugar cane	-0-	-0-	2.00	14.00	-0-	-0-	41.00	2.00	2.00	-0-	-0-	8.00
Rice	8.00	22.00	18.60	25.00	6.29	15.34	59.00	17.55	5.32	-0-	40.32	32.00
Cotton	1.50	14.00	4.00	10.00	-0-	-0-	-0-	-0-	-0-	-0-	-0-	12.00
Peanuts	3.80	1.00	1.00	1.00	5.94	-0-	-0-	-0-	-0-	-0-	-0-	7.00
Soybeans	1.32	-0-	-0-	-0-	10.00	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Non-Mechanized												
Corn	24.00	3.66	2.88	-0-	40.74	11.00	-0-	21.00	43.68	-0-	20.70	-0-
Beans	1.00	2.00	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Sugar cane	25.00	-0-	-0-	-0-	1.00	1.00	-0-	-0-	-0-	-0-	3.00	-0-
Rice	6.00	-0-	1.4	-0-	30.71	10.66	-0-	9.45	8.68	-0-	22.68	-0-
Cotton	4.50	-0-	-0-	-0-	4.00	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Peanuts	1.2	-0-	-0-	-0-	.06	9.00	-0-	-0-	-0-	-0-	-0-	-0-
Soybeans	4.68	-0-	-0-	-0-	-0-	9.00	-0-	-0-	-0-	-0-	4.00	-0-
Total	100	100	100	100	100	100	100	100	100	100	100	100

Although the non-mechanized farms tend to be less specialized, the combination of the mechanized and non-mechanized farms will result in each of the twelve representative farms tending to produce at least three or more products. However, as Table 4.2 indicates, the cropping pattern tends to be much more specialized in the optimum solution. In no case does the optimum plan indicate that the farm should produce more than two crops, and in eight of the twelve cases it indicated that the farm should specialize in only one crop.

There is also an important shift in the crops produced. The farmers currently are concentrating on corn and rice, with sugar cane being in third place. However, in only one of the optimum plans did corn enter the solution. Sugar cane entered with much more frequency, as did peanuts. The only three crops which entered the optimum plans with any frequency were sugar cane, rice, and peanuts.

The extension staff in the State of Sao Paulo are recommending that farmers plant soybeans and have an extensive campaign to this end under way. It is interesting to note that soybeans did not enter a single optimal plan, even though the yields used in the programming are reasonably good.

The optimum plans tended to indicate that the farmers should use all of the pasture available. The one exception was the Extra Large Livestock Farm in Region 1, which the

Table 4.2. Percentages of Cropland Used in the Various Crop Production Activities, Optimal Farm Organization for Each Size of Farm, Study Area, Sao Paulo, 1966 to 1967 Crop Year.

	Crop Farms							Livestock Farms				
	Region 1				Region 2			Region 1			Region 2	
	Small	Medium	Large	Extra Large	Small	Large	Extra Large	Small	Large	Extra Large	Small	Large
Mechanized												
Corn	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Beans	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Sugar cane	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Rice	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Cotton	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Peanuts	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Soybeans	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Non-Mechanized												
Corn	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	46.29	-0-
Beans	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Sugar cane	52.68	8.02	-0-	-0-	35.34	-0-	-0-	100	-0-	-0-	-0-	-0-
Rice	47.32	-0-	-0-	-0-	-0-	100	100	-0-	-0-	-0-	53.71	-0-
Cotton	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Peanuts	-0-	91.98	100	100	64.66	-0-	-0-	-0-	100	100	-0-	100
Soybeans	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Total	100	100	100	100	100	100	100	100	100	100	100	100

program indicated should rent out 1,116 hectares of his total of 1,196 hectares of pasture. In the process, the plan indicated that this farm should reduce its milk cows from 425 to 64 (see below). This latter result is a bit surprising and may indicate an over-evaluation of the rent the farmer can receive for his pasture. However, the rent figure used was the average of what farmers in the region paid.

The model did not permit the farmers to rent pasture, even though this practice is fairly common in the study area. The model did permit the conversion of cropland to pastures, but this never appeared in an optimum plan.

Livestock Production

Substantial shifts were also indicated for the livestock enterprises. As Table 4.3 indicates, swine is currently produced on all of the farms except two, and in some cases in substantial numbers. However, swine did not enter in the optimum plan of a single representative farm.

In addition to specializing in milk production, the optimum plans tend to indicate that the representative farms should increase the number of milk cows that they have. In all except two cases the program indicates that the number of milk cows should be increased, and in most cases the indicated increase is fairly substantial. The most significant

Table 4.3. Livestock Production, Actual and Optimal Plans, Study Area, Sao Paulo, 1966 to 1967.

Region	Farm Type	Farm Size	Livestock	Actual Plan	Optimal Plan
				(heads)	(heads)
1	Crop	Small	Milk cows	6	4
1	Crop	Small	Swine	10	0
1	Crop	Medium	Milk cows	22	23
1	Crop	Medium	Swine	18	0
1	Crop	Large	Milk cows	47	100
1	Crop	Large	Swine	53	0
1	Crop	Extra Large	Milk cows	216	436
1	Crop	Extra Large	Swine	22	0
2	Crop	Small	Milk cows	10	14
2	Crop	Small	Swine	16	0
2	Crop	Large	Milk cows	38	127
2	Crop	Large	Swine	57	0
2	Crop	Extra Large	Milk cows	121	659
2	Crop	Extra Large	Swine	0	0
1	Livestock	Small	Milk cows	25	26
1	Livestock	Small	Swine	10	0
1	Livestock	Large	Milk cows	56	88
1	Livestock	Large	Swine	13	0
1	Livestock	Extra Large	Milk cows	425	64
1	Livestock	Extra Large	Swine	0	0
2	Livestock	Small	Milk cows	19	29
2	Livestock	Small	Swine	17	0
2	Livestock	Large	Milk cows	56	160
2	Livestock	Large	Swine	43	0

decrease is the above-mentioned case when the farm rents out his large supply of available pasture and reduces his milk cows from 425 to 64.

In two cases the indicated number of milk cows is quite large (436 and 659). In these cases, management limitations may be a problem, but it is important to recognize that milk production in Brazil is a fairly extensive operation and could be manageable with a decentralized form of management.

Resources Use

Perhaps the most striking finding with respect to resource use was that mechanization (tractor power) is not a viable activity in any of the optimum plans, even though tractor power is reasonably common in the study area. Many students of Brazilian agriculture recommend the mechanization of its agriculture, and the government currently has a rather intensive program to this end. The results of the present study indicate that, given the price relationships used, this is not rational. The interesting point is that the price of labor is higher in Sao Paulo than in any part of Brazil, and yet it is still not viable.

It may be that factors other than the relative prices of products and factors enters into this result. For example, it is rather difficult to capture the dimension of improved timeliness which comes from using tractor power.

In addition, a tractor may not be economical given the relatively small acres devoted to crops. However, other studies have indicated that the price relatives of tractors do argue against their use under present conditions.[2/]

The results with the labor input were equally as interesting. Labor was divided into two categories -- permanent and temporary -- to reflect actual hiring conditions in the study region. Permanent labor is family labor plus hired labor that is contracted for a one-year basis. Temporary labor is hired for only short periods of time, and usually only in the harvest season of May and June.

The model did not permit the hiring or selling of its permanent labor due to the short-run nature of the planning horizon. This is not as unrealistic as it might seem since the costs of firing a laborer under present Brazilian labor legislation is rather high.

The results of the analysis indicate that this was not a bad assumption. At least the results do not indicate large amounts of permanent labor that was not utilized. Only the Small Crop Farm in Region 2 indicated that some permanent labor should be left idle and this in Period 1.

In general, the results of the optimum plans indicate that the farmers should employ more labor, which under the

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2/ See G. Edward Schuh, The Agricultural Development of Brazil, Praeger Press, (Forthcoming), 1968.

conditions of the models comes in as temporary labor. In addition, the results indicate that temporary labor should be hired throughout the year, rather than just in Period 2, the harvest season (see Table 44). In some cases the optimum plans indicate that no temporary labor is needed in the harvest period, even though the farms are currently using it.

With respect to credit, the optimum plans indicate that in general this is not necessary. Only three of the representative farms had optimum plans which indicated the use of borrowed operating capital. Of these three, only two involved substantial amounts of money.

These results suggest that the income flow of the farms is sufficient to provide the necessary operating capital, after an allowance is made for the provision of a family living allowance. This may be a reflection of the relative importance of dairying in the region, which provides a rather continuous income flow. Alternatively, it may reflect the lack of detail in the programming model itself. An analysis of credit needs within the various periods of the year might indicate the need for larger quantities of short term credit.

Net Income to Fixed Factors

A comparison of the net income to fixed factors from the optimum plans with those actually realized on the

Table 4.4. Temporary Labor Hired As A Percentage of the Total Actual and Optimal Plans in Each Period, Study Area, Sao Paulo, 1966 to 1967.

Region	Farm Type	Farm Size	Period	Actual Plan Percent of (man-days)	Optimal Plan Percent of (Man-days)
1	Crop	Small	1	0	25
1	Crop	Small	2	23	27
1	Crop	Medium	1	0	7
1	Crop	Medium	2	22	0
1	Crop	Large	1	0	65
1	Crop	Large	2	48	7
1	Crop	Extra Large	1	0	15
1	Crop	Extra Large	2	12	0
2	Crop	Small	1	0	0
2	Crop	Small	2	19	0
2	Crop	Large	1	0	37
2	Crop	Large	2	19	26
2	Crop	Extra Large	1	0	53
2	Crop	Extra Large	2	39	20
1	Livestock	Small	1	0	27
1	Livestock	Small	2	7	23
1	Livestock	Large	1	0	22
1	Livestock	Large	2	18	0
1	Livestock	Extra Large	1	0	16
1	Livestock	Extra Large	2	0	0
2	Livestock	Small	1	0	2
2	Livestock	Small	2	41	12
2	Livestock	Large	1	0	59
2	Livestock	Large	2	36	8

representative farms is presented in Table 4.5. This table indicates that, to the extent that the analysis is valid, net incomes to the fixed factors can be increased if the optimum plans are adopted. In every case the net income from the optimum plan is greater than the representative farms were actually realized. In some cases the increases are really substantial, and the smallest increase was 18 percent. The average increase was 60 percent.

Sensitivity of the Optimum Plan

It is rather difficult to summarize the results with respect to the sensitivity analysis. It seems fair to say that in general the plans are not sensitive to changes in the parameters in the models, although there are important exceptions. The most common parameters to which the results were sensitive were the prices of the crops and the initial resource availabilities. At times the results were sensitive to the change in yields of omitted crops.

Policy Implications

The results of the analysis have important policy implications. Perhaps the most important derives from the relatively large income gains which the analysis suggests can be obtained from improved farm organizations. If the government is interested in increasing the welfare of

Table 4.5. Net Income to Fixed Factors, Actual and Optimal Plans, Study Area, Sao Paulo, 1966 to 1967.

Region	Farm Type	Farm Size	Actual Plan[a/] NCr$	Optimal Plan NCr$
1	Crop	Small	- 2200	8458
1	Crop	Medium	865	19905
1	Crop	Large	13912	65210
1	Crop	Extra Large	43918	53909
2	Crop	Small	207	5775
2	Crop	Large	7534	52184
2	Crop	Extra Large	20727	155259
1	Livestock	Small	1828	11704
1	Livestock	Large	2069	31400
1	Livestock	Extra Large	9887	29824
2	Livestock	Small	5257	13330
2	Livestock	Large	7310	29859

a/ The estimated actual incomes are calculated subtracting the variable costs as temporary labor, seeds, insecticides, medicine, and fuel, from the sale and home consumption of livestock and crop production and change in the real value of inventories.

rural people, these results suggest that farm management research can be useful to this end.

Economic research is sorely lacking in Brazil. These results suggest that research of the present kind can be useful in increasing the welfare of rural people.

These implications go beyond the immediate welfare of rural people, however. The results of the research indicate that resources in the study area are not being used in an optimal manner. Were they to be utilized in an optimum manner, a larger product would be forthcoming and the Brazilian consumer would benefit from lower food prices, or additional resources would be freed up for the production of non-food products. This is another important motivation for additional farm management research.

An important corollary of the need for additional research is the need for an extension program. The results of research can be effective only when they are adopted by the respective decision-makers.

It would appear that there are two aspects to this problem. On the one hand, there is the need to place the results of farm management research such as the present in the hands of the farm decision-makers. But in addition to this, it is also important to teach the principles of farm management to farm operators so that they can improve their own management ability.

An additional dimension to this problem is the need to provide to farm decision-makers the basic data on which operating decisions are based. This includes information on technical production possibilities as well as information on current prices and price trends. This provides further impetus to the need for additional research and extension.

One of the findings of the research was that the farms should be more specialized in their crop production. One of the reasons they may not do this is because of the uncertainty they face from variations in yields and prices. (Diversification can be conceived as an informal insurance scheme). If this is the case, forward price programs which guarantee the price to the farmer at the time he makes his production decision may lead to increased specialization and to the benefits derived therefrom.

The Brazilian government is now attempting to stimulate the tractor mechanization of the agricultural sector. The results of the present reseach indicate that this program would be wrong, at least under present conditions. However, efforts directed at creating the conditions necessary for mechanization may be well founded. In other words, policies which lower the real price at which tractors can be supplied in Brazil, or which increase the value of the human agent so that he receives a higher wage, may be wiser than propaganda programs aimed at increasing the use of tractors.

The results of the research also indicate that the need for credit is not of high priority. At best the credit needs are rather selective. It should be recognized, however, that the models used do not permit a complete analysis of the use of credit on farms.

The employment of labor is an important problem in Brazil. The present research indicates that there are important employment possibilities in the study area. Public information programs which indicate to the farmer that he could profitably hire more labor, and which indicate to the laborers where employment possibilities exist, can have an important effect on total social welfare.

Suggestions for Future Research

Suggestions for future research are based on the limitations of the present study and on new avenues of research which the present study suggests. These aspects will be discussed in the section in an interrelated way.

Perhaps the most serious limitation of the present study is the technical production coefficients on which the analysis is based. For the most part, the coefficients were taken from the questionnaires, and to this extent should represent conditions in the study region. However, they vary a great deal among farms and are especially subject to measurement error. This problem is complicated by the small numbers of farms on which some of the coefficients are based.

A major effort should be addressed to developing realistic and representative coefficients on which the modern tools of programming can be based. The results from these powerful tools can be no better than the basic data which go into them.

The second limitation of the model was the detail of analysis which it permitted. This is, of course, related in part to the lack of coefficients for a more refined analysis. Perhaps the more important aspects of this have to do with the use of credit and labor. More refinement which would permit more detailed analysis of the within-the-year use of these resources would be useful.

Logical extensions of the models could also provide important results, especially if combined with complimentary studies. For example, more information on the employment opportunities of labor would permit a more careful analysis of labor use. Programming of the model under a range of prices would indicate how the farm organization should change under alternative conditions. This, together with information on the frequency of price relatives from time series data would provide insight into the risk and uncertainty problem and provide a means of developing more rational strategies.

Finally, the models can be used to make analysis of more direct use in policy matters. For example, supply curves for product can be developed, as well as demand curves for the inputs. Both of these are useful for aggregate planing purposes. Programming with this purpose in mind should allow for externalities, however.

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APPENDIX A

THE SAMPLE

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THE SAMPLE

The universe from which the sample was drawn is formed by three counties, Sao Joaquim da Barra, Orlandia, and Sales de Oliveira. These three counties are located in the northern part of the State of Sao Paulo. (See Figure A.1). A list of properties was obtained from the county tax offices. The universe was first divided into eleven strata, according to the farm size (Table A.1).[1/] Due to the small number of farms in strata eleven (only three), it was omitted.

The strata then were grouped in four classes of farms, and an attempt was made to obtain an equal number of farms in each strata, with a larger sample taken among the small farms. Within each strata, the farms to be interviewed were selected by a random process. Data on the sampling rates are presented in Table A.2.

1/ The farms with less than 10 hectares were neglected.

Figure A.1. Brazil With the Location of the Study Area in the State of Sao Paulo

Table A.1. Farm Distribution in Eleven Strata Of Size, Study Area, Sao Paulo, 1966.

Strata	Ranges	Orlandia	Sales de Oliveira	Sao Joaquim da Barra
	(hectares)			
I	10-25	15	35	56
II	26-50	16	32	54
III	51-75	9	17	24
IV	76-100	3	7	12
V	101-150	3	10	16
VI	151-200	5	12	14
VII	201-250	1	7	7
VIII	251-500	3	19	13
IX	501-1000	7	6	18
X	1001-2400	8	7	4
XI	More than 2400	2	0	1

Source: Registration files in the County Tax Office of Orlandia, Sao Joaquim da Barra, and Sales de Oliveira.

Table A.2. Class Ranges and Sample Size, Study Area, Sao Paulo, 1966.

Classes	Ranges	Orlandia	Sales de Oliveira	Sao Joaquim da Barra	Total	Sample
	(hectares)					
I	10-50	31	67	110	208	34
II	51-100	12	24	36	72	14
III	101-250	9	29	37	75	18
IV	251-2400	20	32	36	88	13

APPENDIX B

DEVELOPMENT OF THE REPRESENTATIVE FARMS

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To synthesize the representative farms, tests of homogeneity were carried out. The first comparison programmed was with respect to the homogeneity of the three counties. These tests were based on corn yields, rice yields, capital per hectare and income per hectare (Table B.1).

The tests indicated that the farms from Sao Joaquim da Barra and Sales de Oliveira could be considered homogeneous and could be grouped together, while those from Orlandia were statistically different from the others in enough respects to be treated separately.

After having the two regions defined, the farms in each region were divided into two groups according to type of farming, crop and livestock farms. This division was based on the percentage of gross income from crop and livestock production. The farms in which 40 percent or more of their gross income were from livestock production were considered livestock farms and the others were classified as crop farms.

Table B.1. Homogeneity Tests for Three Counties, Study Area, Sao Paulo, 1966.

Comparison	Basis	d.f.	F
Sao Joaquim da Barra vs. Orlandia	Corn yields	1-54	3.72*
Orlandia vs. Sales de Oliveira	Corn yields	1-52	6.58**
Orlandia vs. Sao Joaquim da Barra	Rice Yields	1-54	3.58*

* Significant at 10 percent level.
** Significant at 5 percent level.

An analysis of variance was made to test the homogeneity of these different types of farms. The basis for these analyses of variance was corn yields, rice yields, capital per hectare, gross income per hectare, and liters of milk per hectare of pasture. The tests indicated that the null hypothesis, that is, that the farms of different types were equal, could be rejected (Table B.2). Significant differences did not arise in all cases, but did arise with sufficient frequency to merit treating them as separate entities.

Finally, for each type of farm in each region, tests of homogeneity were again made to verify the homogeneity of farms in different sizes. The basis for these tests was also corn yields, rice yields, capital per hectare, gross income per hectare, and liters of milk per hectare of pasture. The tests showed that the farms in each region and of a particular type were not homogeneous according to size (Table B.3).

In developing the size classes, judgment was used in deciding what were meaningful size ranges. The test is at best a rather crude test, but does indicate that there are differences among the size classes.

The distribution of farm sampled among the representative farms can be seen in Table 1.2. The range in farm size within each class is given in Table B.4.

Table B.2. Homogeneity Tests for Different Types of Farms, Study Area, Sao Paulo, 1966.

Comparison	Basis	d.f.	F
Crop type, Region 1 vs. Livestock type, Region 2	Corn yields	1-45	6.40***
Livestock type, Region 1 vs. Livestock type, Region 2	Corn yields	1-25	4.33**
Crop type, Region 1 vs. Livestock type, Region 1	Rice yields	1-46	4.10**
Livestock type, Region 1 vs. Crop type, Region 2	Rice yields	1-30	13.13***
Livestock type, Region 1 vs. Livestock type, Region 2	Rice yields	1-25	3.67*
Crop type, Region 1 vs. Livestock type, Region 1	Milk/hectare	1-46	3.31*
Crop type, Region 1 vs. Livestock type, Region 2	Milk/hectare	1-45	4.12**
Livestock type, Region 1 vs. Crop type, Region 2	Milk/hectare	1-30	6.38***
Crop type, Region 2 vs. Livestock type, Region 2	Milk/hectare	1-29	10.88***

* Significant at 10 percent level.
** Significant at 5 percent level.
*** Significant at 1 percent level.

Table B.3. Homogeneity Tests for Different Sizes of Farms Within Each Region and Type of Farm, Study Area, Sao Paulo, 1966.

Region	Type	Comparison	Basis	d.f.	F
1	Crop	Small vs. medium	corn yields	1-21	3.99*
1	Crop	Small vs. Extra Large	income/ hectare	1-18	6.01***
1	Crop	Medium vs. Extra Large	income/ hectare	1-9	5.19**
1	Crop	Small vs. medium	milk/ hectare	1-21	8.84***
1	Crop	Medium vs. Large	milk/ hectare	1-12	3.40*
2	Crop	Small vs. Large	corn yields	1-15	6.93***
2	Crop	Small vs. Large	milk/ hectare	1-15	4.56**
2	Livestock	Small vs. Large	capital/ hectare	1-11	5.14**
2	Livestock	Small vs. Large	milk/ hectare	1-11	6.46**

* Significant at 10 percent level.
** Significant at 5 percent level.
*** Significant at 1 percent level.

Table B.4. Farm Size Ranges Within Each Class, Study Area, Sao Paulo, 1966.

Region	Farm Type	Farm Size	Ranges	Number of Farms
			(hectares)	
1	Crop	Small	20 - 75	16
1	Crop	Medium	76 - 150	7
1	Crop	Large	151 - 500	7
1	Crop	Extra Large	501 - 1330	4
2	Crop	Small	10 - 100	8
2	Crop	Large	101 - 600	5
2	Crop	Extra Large	601 - 1000	1
1	Livestock	Small	20 - 100	13
1	Livestock	Large	101 - 250	4
1	Livestock	Extra Large	251 - 1210	1
2	Livestock	Small	20 - 100	8
2	Livestock	Large	101 - 450	5

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