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Economic Analysis of the Agricultural Sector in Santa Cruz, Bolivia

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ECONOMIC ANALYSIS OF THE AGRICULTURAL SECTOR IN SANTA CRUZ,

BOLIVIA

by

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of

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Enrique Gómez

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ABSTRACT

Economic Analysis of the Agricultural Sector in

Santa Cruz, Bolivia

by

Enrique Gómez, Doctor of Philosophy

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Major Professor: Dr. B. Delworth Gardner
Department: Economics

A linear programming technique is used to calculate the land allocation that maximizes the returns to the agricultural producers in the provinces Santisteban, Sara, Warnes, Ibáñez, and Ichilo, in the department of Santa Cruz, Bolivia, under different sets of prices.

All the input requirements per unit of land and average expected yields are estimated from survey data collected from farmers in Bolivia. Constraints on availability of land and labor are also estimated.

Seven crops are included in the model: soybeans, wheat, cotton, yuca, sugar cane, rice, and corn.

The model is first examined under the set of prices that existed prior to the 67 percent devaluation of the Bolivian currency of October 1972. Supply schedules are calculated for each one of the crops. Later, the price changes caused by the devaluation are introduced into the model, and their impact upon the "optimum" land allocation in the area is ascertained.

A supply curve is derived for cotton under "after devaluation" prices. The effect of an export tax, on land utilized for cotton production is analyzed. It is estimated that a 40 percent tax on cotton

production, other things being equal, would render cotton production unprofitable. A 23 percent tax would maximize the Government tax revenues. The net social cost of implementing such a tax is estimated at $b 101.6 millions per year.

A self-sufficiency national policy is examined for wheat production. If the Government desires self-sufficiency in wheat production while maintaining the real price to the consumers at the pre-devaluation level, (that is, $b 46.75 per cwt before devaluation, and $b 70.12 per cwt after) the producers would have to be paid $b 150.0 per cwt, the difference between the pegged consumer price and the price paid to producers being covered by a Government subsidy. The total cost to the Government for the subsidy is estimated at $b 642.7 millions per year, and the net social loss is $b 141.2 millions per year.

(190 pages)

CHAPTER I

INTRODUCTION

Description of the Area

This study is concerned with the agricultural area south of the triangle formed by the Rio Grande and Ichilo rivers, in the department of Santa Cruz, Bolivia. It includes the provinces Ibáñez, Santisteban, Sara, Warnes, and Ichilo (see Figure 1).

In a country characterized by a traditional subsistence-type agriculture with slow and limited responses to market incentives, the Santa Cruz area presents a contrasting picture of rapid growth and a high response to market incentives. Gross agricultural product in the region increased at an average annual rate of 7.5 percent between 1950 and 1968.[1]

The apportioning of land into small farms initiated by the Land Reform of August, 1953 has been limited to the traditional agricultural areas and was not extended to the area of Santa Cruz. In contrast to the rest of the agricultural areas in Bolivia, Santa Cruz has maintained a pattern of land ownership that permits the development of large-scale, commercial-type agriculture. Product and factor markets in the area tend to be more developed than in the rest of the country. Nature is also more beneficent as the Santa Cruz area has plentiful rainfall, but

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[1] Análisis Socioeconómico del Departamento de Santa Cruz de la Sierra (Bolivia), Comisión Económica para America Latina, United Nations. Vol. IV, p. 2, April 1972.

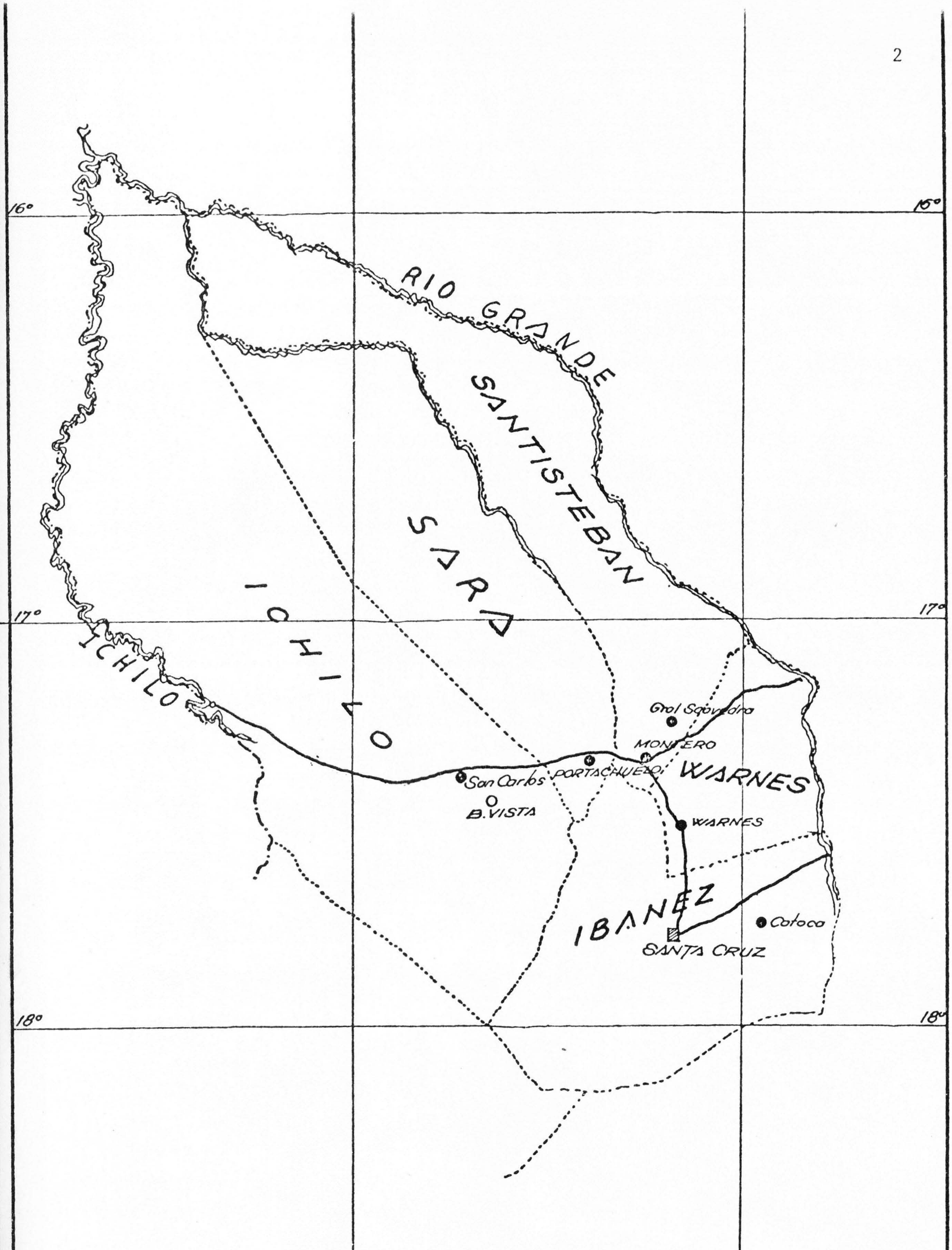

Figure 1. Map of Areas Included in this Study. (Scale 1:1,500,000)

not uniformally distributed. The lower altitude makes agricultural production more profitable than in the other areas of Bolivia.

A significant amount of public investment has been channeled into the area in the last 25 years, mainly for the construction of the paved road between Cochabamba and Santa Cruz, the railroad connections to Argentina and Brazil, colonization projects, exploitation of oil and natural gas, and the construction of the Guabirá sugar mill.

Nature of the Problem

Even though the Bolivian government has been looking at the Santa Cruz area as the greatest potential source of agricultural development in the country since the 1950's, it is only in recent years that this area has started to develop its capability to introduce modern techniques of production, new crops, and rapid shifts from one crop to another in response to economic incentives.

A cotton production boom has occurred in the last three years, starting from 7,500 hectares in 1970, to 17,600 hectares in 1971, and an estimated 47,100 hectares in 1972.[2]

The introduction of this crop, which is characterized by the use of modern technology (improved seeds, herbicides, insecticides aerial spraying, tractor plowing, etc.) has been stimulated by a favorable gradual increase in the world market price (Table 1).

Cotton production is also important because it is grown mostly for export (only about 15 percent of the total production in 1972 went to domestic consumption), and because it makes intensive use of labor for harvesting (more than 50,000 laborers were expected to be brought from

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[2] No estimates of agricultural production in 1972 are yet available.

Table 1. Cotton production in Santa Cruz

Years	Cultivated areas hectares	Production cwt	Price US$/MT
1967	4,500	68,000	---
1968	4,860	81,000	---
1969	6,000	111,000	530
1970	7,500	225,000	554
1971	17,600	612,300	627

outside the area for the 1973 harvest), thus creating a significant short term labor deficit in the area.

In order to accommodate such a sudden growth in the hectareage devoted to cotton, other crops, namely sugar cane, corn, and rice had to be displaced.

Before 1971, the prices paid to sugar cane producers at the mills were at a fixed level of 66 $b/MT, set by the government.[3] Since this was not an equilibrium price, it caused production surplusses that could not be economically exported (that is, exports other than the subsidized quotas assigned by the US) because of the high transportation costs involved. The government responded by establishing production controls in the form of marketing quotas assigned to a selected group of farmers, who sometimes did not produce sugar cane at all, but bought it at lower prices from the farmers in the newly colonized areas, who do not have a quota, and sold it to the sugar mills at a profit.

The upshot of these government policies and increasing competition from cotton, was that sugar cane production dropped from 1,303 metric tons in 1969, to 1,187 in 1970, and only 759 in 1971 (Table 2). Because

[3]Bolivian pesos per metric ton.

Table 2. Sugar cane production in Santa Cruz

Years	Cultivated areas hectares	Production MT x 1000	Price $b/MT[1]
1967	29,750	993	66
1968	32,950	1,106	66
1969	36,900	1,303	66
1970	N.A.	1,187	66
1971	15,545	759	66

of political reasons, the government was reluctant to revise the quotas until 1971 when it became necessary to import about 40 percent of the total domestic consumption of the country, with a loss of foreign exchange of about 6 million dollars (US). To overcome this production deficit, the government first decided to reassign the quotas in 1971, and also raised the prices paid to sugar cane producers in 1972.[4] Although this is not an annual crop, the response to the new incentive price has covered the deficit for the 1972 harvest, and might result in production surpluses in the next few years if the quota system is not very rigid, as new areas come into production.

Santa Cruz accounts for about 80 percent of the total national production of rice, and the amount of land devoted to rice production has shifted markedly (Table 3).

Milled rice is purchased by the Agricultural Bank which is charged with marketing the entire national production, but farmers have the option of either taking their crop to the rice mills and then selling the hulled rice to the Agricultural Bank, or just selling it

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[4] The price was subsequently increased to 92 $b/MT.

Table 3. Milled rice production in Santa Cruz

Years	Cultivated areas hectares	Production MT	Popular	Extra
			$b/cwt	
1967	30,700	39,700	60	90
1968	33,900	45,900	56	90
1969	49,300	58,400	60	87
1970	49,800	45,000	57	82
1971	41,500	37,500	70	84

directly to a mill at a lower price.

It is difficult to assess the size of the surplus in rice production. Export possibilities have been enhanced by the 67 percent devaluation of the Bolivian currency relative to the US dollar, brought about in 1972.

There are no available time series data on corn production. The prices that appear in Table 4 are the prices obtained by the cooperation of the San Juan colony in the city of Santa Cruz.

Table 4. Corn prices in Santa Cruz[a]

Year	Price $b/cwt
1967	20.0
1968	20.0
1969	22.8
1970	17.3
1971	13.6

[a]No data were available on production estimates.

Due to the lack of storage facilities, corn prices fluctuate widely during any given year from around 12 to 50 $b/cwt. No price control policies exist for this crop, and in 1972 a severe shortage of production sent corn prices upward. As a result, the poultry producers, who had their profits reduced by absorbing the increase in the price of corn, protested since they argued that they could not raise their poultry prices because of competition from the cattle industry.

It must be obvious from the foregoing examples that the government is active in many ways in intervening in the markets of the agricultural sector. The government has established price controls and marketing policies that have been combined recently with the devaluation of the Bolivian currency. Heavy new taxes on all cotton exports and price subsidies to wheat production have been created.[5] A prominent national goal is to reach self-sufficiency in wheat production.

Objectives

The objectives of this study are:

1. To assess the impact of selected government policies upon the optimum land allocation to various crops in the area.
2. To estimate their effects on the total net returns to the agricultural sector.

More specifically, the following sub-objectives will be examined.

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[5]The purpose of creating these export levies seems to be to tax away the excess profits the cotton producer caused by the sudden devaluation of the Bolivian currency. An equal tax was put on all commercial inventories of imported commodities.

<u>To determine land allocation among crops that maximize net returns to the agricultural sector under the prices that existed before the devaluation</u>

In theory, an optimum distribution of a fixed quantity of available agricultural land among the various competing crops will occur when the marginal value products of all land for all crops are equal.

This optimum allocation of land will be calculated using linear programming. The value of the objective function (net returns to the agricultural producers) will be maximized under the set of constraints specified in the model. An "optimum solution" will be obtained for each assumed set of prices. These "optimum solutions" are not necessarily identical to the "true optimum" (if in fact a "true optimum" exists) because they are defined by the assumptions introduced into the model in the product and factor prices, input-output coefficients and constraints on land, production, and availability of factors of production. The model does not reflect the inherent differences between individual farmers or individual farms (soil and climate characteristics), but estimates the averages to be entered into the program.

To the extent that the assumptions entered into the model differ from the real world and the model is restricted to linear functions, the "optimum solutions" calculated will also diverge from the "true optimum".

Because the optimizing technique utilizes fixed coefficients, however, land will be allocated to the crops yielding the highest per hectare profit until a land constraint of some kind is reached.[6] Then

[6]The linear program used was run on a Burroughs B6700 computer with a Tempo MPS/MPS program that requires the same data input format as an MPS 360 IBM program.

the program will allocate land to the next most profitable use, and so on until all the available land is employed. The dual solution of the linear program will yield shadow prices (marginal value products) of the constrained resources.

The crops that will be considered are: sugar cane, wheat, cotton, corn, rice, yuca, and soybeans. The summation of the average expected net returns per hectare of production, times the number of hectares cultivated of each crop in each province will be used as a measure of the total net returns to the agricultural sector. This weighted sum will be the objective function to be maximized under a set of constraints such as availability of land, labor, and capital.

The product and factor prices introduced as coefficients in the linear program will be those that existed in 1972 prior to the devaluation of the Bolivian currency relative to the US dollar. The optimum land allocation obtained will be used as a benchmark to be compared with the results obtained when the devaluation is assumed, and when an export tax is assumed to be in effect.

To determine the land allocation that maximizes net returns to the agricultural sector under different sets of prices produced by the devaluation

The nature of the devaluation. The currency devaluation of October, 1972 in Bolivia was apparently made in order to boost the government revenues from the sale of minerals abroad. In terms of the Bolivian currency, these revenues increased instantaneously by the same proportion as the currency devaluation, while efforts were made to maintain the price of domestic inputs at their pre-devaluation levels.[7]

Prior to the devaluation, the retail prices of many food items were pegged below equilibrium levels by the government, among them beef, rice, sugar cane, oil, and wheat. The devaluation produced an instantaneous 67 percent increase in the Bolivian pesos ($b) prices of export products (price equals world market price in dollars minus transport costs to the purchasing country) and imported products (price equals market price in dollars plus transportation costs from the producing country). These drastic relative price shifts have led domestic special interest groups to demand changes in their fixed prices. In many cases, the government has yielded to these pressures and the index of domestic prices has increased by 70 percent in the first 6 months after the devaluation, thus mitigating the expected favorable effects of the devaluation on the balance of trade. Furthermore, the government has imposed a new 40 percent export tax on all agricultural products. The effects of this tax on cotton exports have been analyzed also and the results reported in this dissertation.

Not all prices have increased proportionately; wages have risen by less than 70 percent. As a matter of fact, the increase in wages is probably below 40 percent. (This estimate was made in May, 1973.)

Therefore, while product prices of import-export products have increased in one single step by 67 percent, domestic product and factor prices have gradually increased in varying proportions.

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[7] Except for the salary bonuses the government granted to all workers below certain levels.

Assumptions. It is assumed that all prices of imported factors instantaneously increased by 67 percent, the magnitude of the devaluation. All prices of import-export crops are also assumed to increase by 67 percent. All other product and factor prices will be increased parametrically first by 20 percent and then by 40 percent.

Procedure. The same linear program used in the first sub-objective will be run under the new assumed sets of prices. The land allocation that maximizes the value of the objective function (net returns to the producers) will be found for each set of prices to ascertain the effects of the devaluation upon the optimal distribution of the land. The "optimum solution" obtained will be defined by the assumptions introduced into the model. Therefore, it will not necessarily provide with a "true optimum" if the real world conditions depart from the assumptions of the model.

To determine the land allocation that maximizes net returns to the agricultural sector when export taxes on cotton are introduced

Theory and assumptions. The demand curve that producers of cotton face in Bolivia can be probably assumed to be perfectly elastic since Bolivia supplies an insignificant proportion of the world market supply. Any increase in export taxes represents a reduction in the net returns the producer receives from the sale of his crop. It can be represented by a proportional downward shift in the demand function equal to the size of the tax.[8]

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[8] The price given by the world market demand remains at OA since it is only the net price received by the producer that is lowered by an amount equal to the tax, from OA to OE (Figure 2).

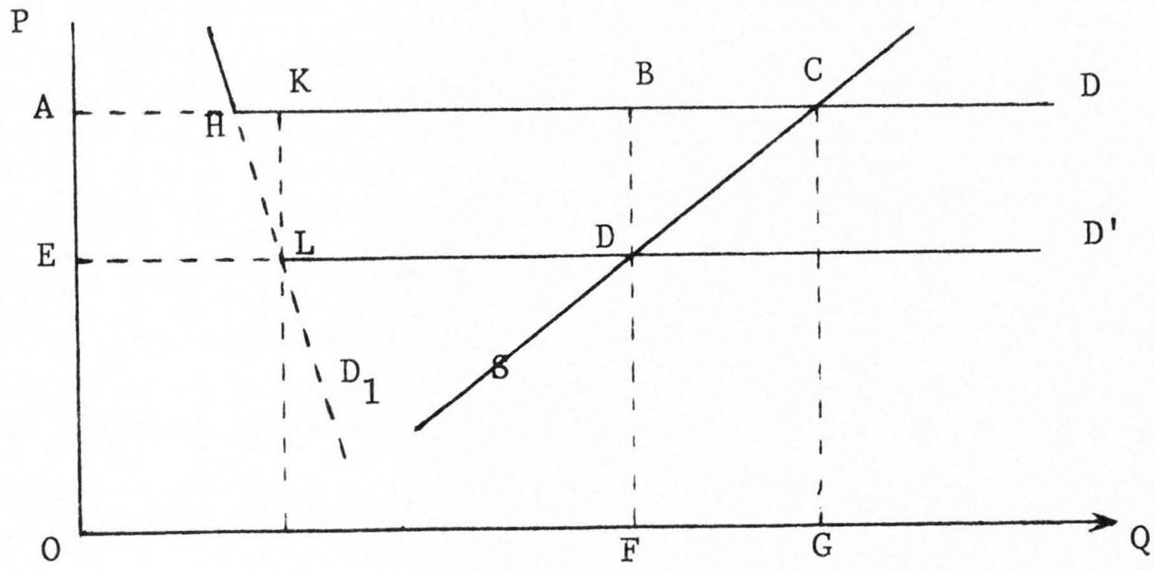

Figure 2. Cotton supply and demand curves.

The net effect of the tax is a reduction in both the price (from OA to OE) and the equilibrium quantity (from OG to OF). (See Figure 2.)

Assuming a constant marginal utility of money and optimum conditions in all other related markets, the loss in producer's surplus attributable to the tax is the area ACDE (Figure 2).[9] D_1 is the domestic demand for cotton. The government taxes would be equal to the area KBDL and represent a transfer from the producers to the government. The gain in domestic consumer's surplus would be AHLE, and the net social loss is the area in the triangles HKL and BDC. If the domestic demand is perfectly inelastic, the loss would be equated only to the area inside BDC.

The supply curve estimated by the model will not be a smooth function but will change stepwise as illustrated in Figure 3.

P_A is the cotton world market price assumed minus transport costs. This amount is also the domestic cotton price OP_A and the quantity of

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[9]John R. Hicks, "The Rehabilitation of Consumers' Surplus," in Readings in Welfare Economics, Kenneth Arrow and Tibor Scitovsky, 1969, p. 330.

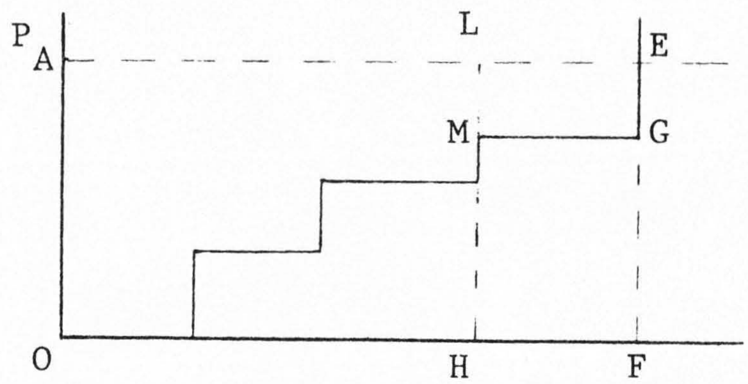

Figure 3. Cotton supply curve estimated by the model.

production at this price is OF. If production is reduced by one unit, the loss in producer's surplus would be equal to FE - FG = EG. The freed resources are allocated to the best alternative, the value of this alternative product being FG. This is also what is accomplished by the linear programming. EG is the reduction in the value of the objective function.

If an exogenous constraint is placed on production limiting the quantity of production to OH, other things remaining constant, the loss in producer's surplus would be equal to the area LMGE, and this is also equal to the reduction in the value of the objective function as indicated by the linear program.

Objective. The objective is to ascertain the shifts in the optimum land allocation of each crop produced, due to the introduction of the tax on cotton exports.

By reducing the quantity of land assigned by the model to cotton production, certain quantities of resources are available to the production of other crops, which were not available previously (land) or were available only at higher prices (labor). Therefore, the overall effect of the tax is not only a reduction in cotton production, but also results in an increase in the production of other crops. No changes in consumer's surplus are provided by the model since constant prices are assumed (perfectly elastic demands). Thus, the overall effect is a loss in producer's surplus, measured by the reduction in the value of the objective function in the model, (that is, net returns to the agricultural producers.)[10] In order to estimate the net social cost of the tax, the export tax revenues are deducted from the overall reduction in producer's surplus.

Procedure. The same linear program of the second sub-objective will be utilized for the export tax analysis, with the prices of products and factors assumed to be the same as indicated in the assumptions in the second sub-objective except those affected by the export tax.

For any given set of prices, the difference between the value of the objective function obtained with the export tax and that with the same set of prices without the export tax (second sub-objective) will provide an estimate of the change in producer's surplus due to the introduction of the export tax. The volume of exports times the value of the export tax will indicate the revenues collected by the government. Total payments accruing to each factor of production will also be calculated.

The optimum land allocation will also be compared in a similar way to ascertain the response to the export tax under any given assumed set of prices. The "optimum solutions" obtained will be defined by the assumptions introduced into the model. Therefore, they will not necessarily provide with a "true optimum" if the real world conditions depart from the assumptions of the model.

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[10] This is discussed in more detail in Chapter V.

<u>To determine the land allocation that maximizes net returns to the agricultural sector when national self-sufficiency of wheat production is imposed</u>

<u>Theory</u>. Two different wheat producing areas are considered: the traditional areas, and the newly colonized areas in Santa Cruz. They are represented by the supply curves S_1 and S_2, respectively. (See Figure 4.) The total supply function for wheat production in Bolivia would result from adding the quantities of S_1 and S_2 at given prices.

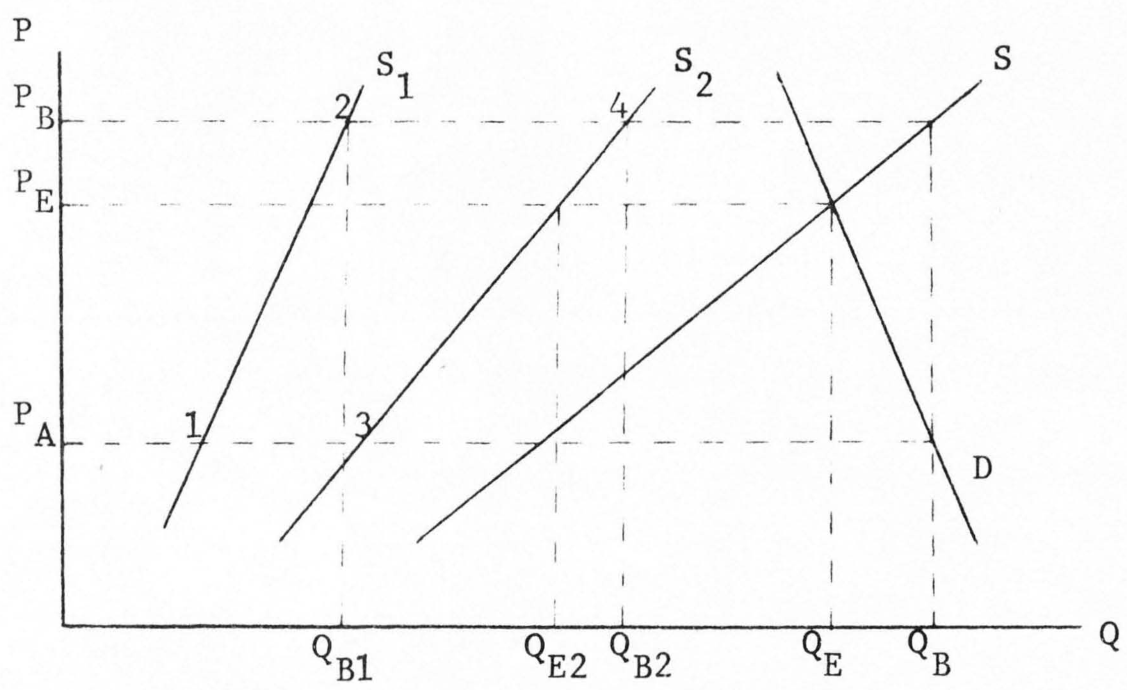

Figure 4. Wheat supply and demand curves.

In order to reach self-sufficiency while maintaining the domestic market price pegged at the present level P_A, it would be necessary to reach a production level of Q_B. The total supply function shows that the subsidy price to wheat would have to be at P_B in order to reach self-sufficiency, with Q_{B1} produced in the traditional areas and Q_{B2} in the Santa Cruz area.

Procedure. To estimate the supply curve of wheat in the traditional areas, the official estimates of wheat production for 1972-73 under the present prices (P_A, Figure 4) will be used as a benchmark point. No direct estimates of the elasticity of supply are available. But supply response estimates for crops grown in Bolivia imply elasticities of supply, and these would seem to be the best data available. Gardner, "The Economics of an Increase in Wheat Production in Bolivia, May, 1966", suggests that a rise in wheat prices from 30 to 50 $b/cwt could be expected to increase production proportionately, implying an elasticity of supply equal to one.

Elasticity of demand will be estimated, and the official estimates of total wheat consumption in the country will be used as an estimate of the self-sufficiency level Q_B. The difference between the fixed assumed total demand D (Figure 5), and the supply curve estimated for the traditional areas constitutes the demand curve facing the non-traditional area of Santa Cruz (D_2, Figure 5).

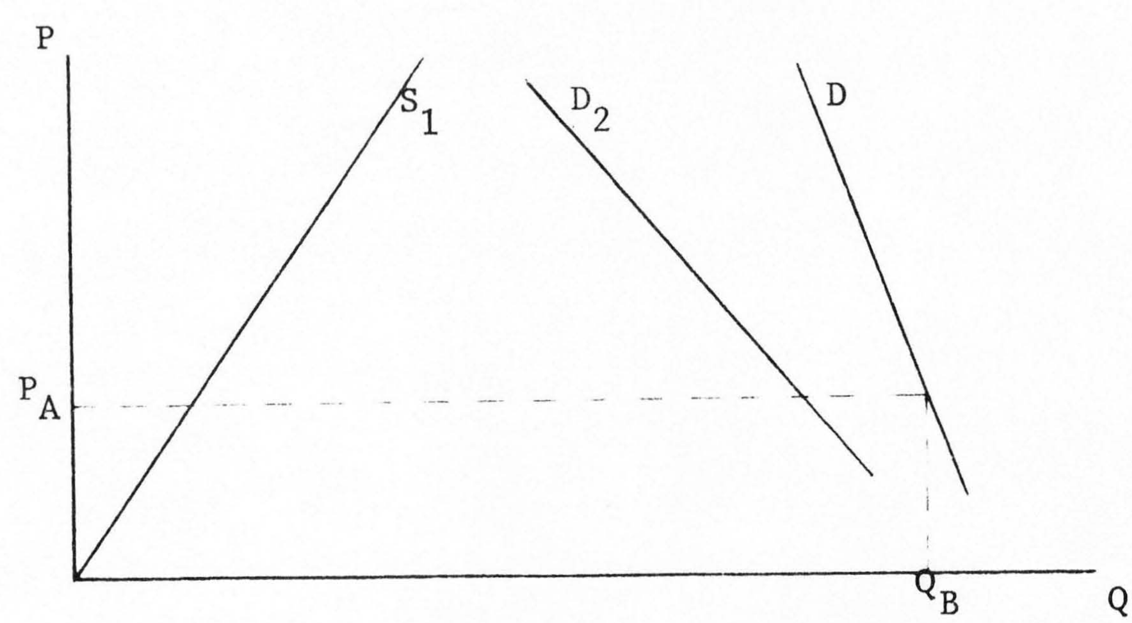

Figure 5. Estimated wheat demand curve facing the Santa Cruz area.

The supply curve of wheat for the Santa Cruz area (S_2) will be estimated by running a post-optimality analysis on the model that allows the price of wheat to be changed while all other things remain constant.[11] The intersection between the supply curve S_2 and the demand D_2 will provide an estimate of the equilibrium price that equates total demand and supply of wheat in the country. (See Figure 6.)

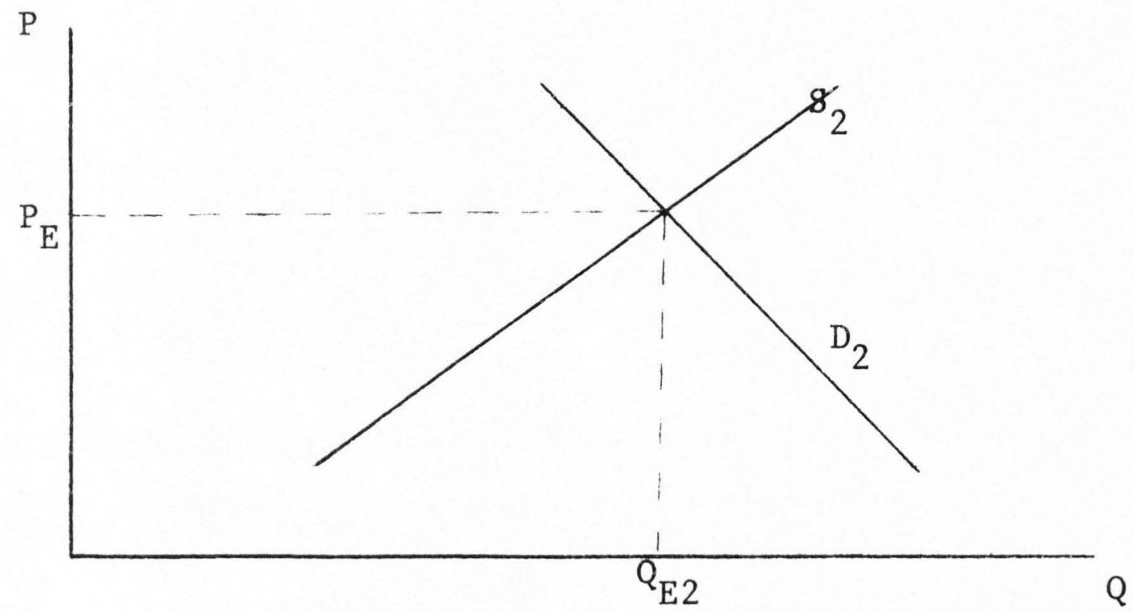

Figure 6. Wheat supply and demand in Santa Cruz.

To estimate the subsidy price necessary to attain self-sufficiency without allowing any increase in the price paid by the consumers, the demand facing the producers of Santa Cruz is estimated by substracting the quantities supplied in the traditional areas, not from the total demand curve as was the case in Figure 5, but from the total quantity demanded at current prices (Q_B):

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[11] Actually, the model allows labor wages to change as total demand intersects total labor supply at different wages along the supply curve, so that S_2 is really a quasi-supply curve.

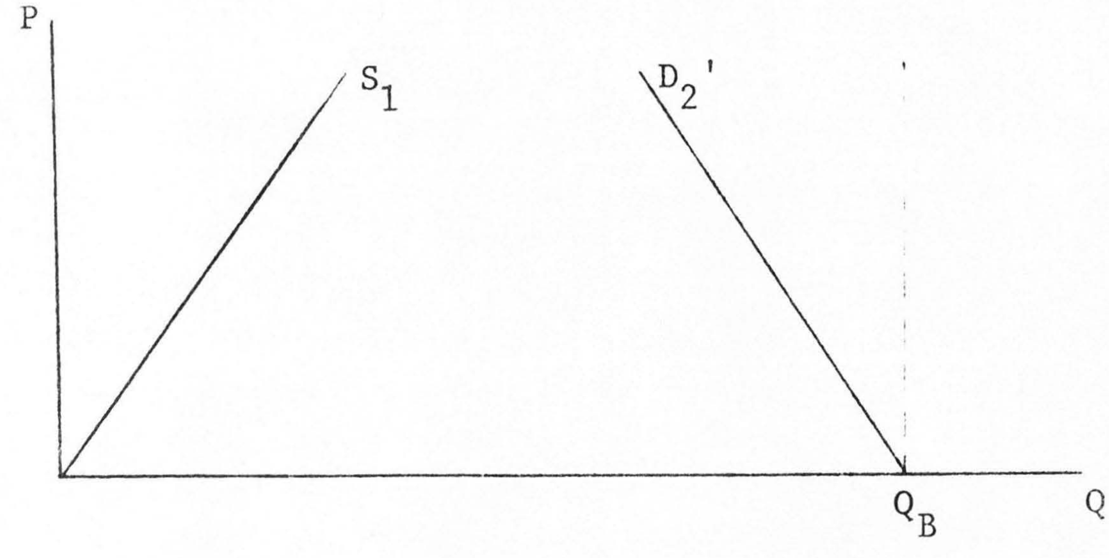

Figure 7. Estimated wheat demand curve in Santa Cruz when a price subsidy is in effect.

The intersection between the new demand curve D_2' and the supply curve S_2 will provide an estimate of the required price subsidy P_B. (See Figure 8.)

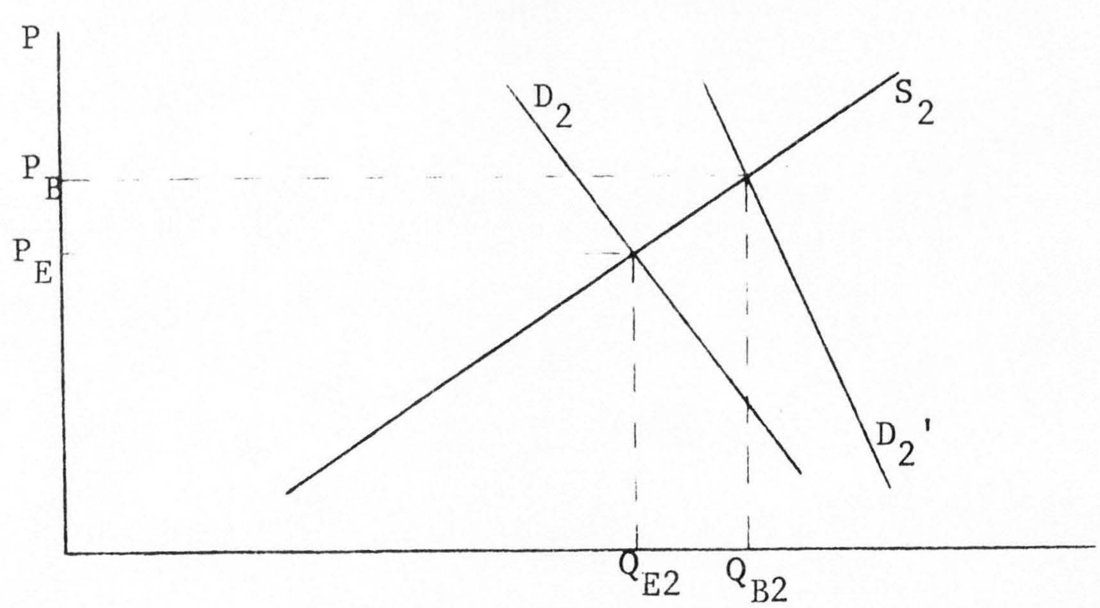

Figure 8. Equilibrium conditions when the price subsidy is in effect.

In order to estimate the loss in social welfare due to the introduction of the price subsidy, the total gain in producer's surplus, both in the traditional and the Santa Cruz areas will be subtracted from the total cost of the subsidy.

If again it is assumed that the marginal utility of money is constant and optimum conditions exist in all other related markets, the gain in producer's surplus in the traditional areas is represented by the area inside $12P_BP_A$ (Figure 4) while the gain in producer's surplus in the Santa Cruz area is given by the area $34P_BP_A$. The difference between P_B and P_A gives the size of the subsidy paid by the government per unit of production, the total subsidy being the area P_B minus P_A times OQ_B. (See Figure 4.)

Data Sources

Most of the data used in this study were obtained from two questionnaire surveys, one relating to agricultural production and the other to costs of production. Both surveys were prepared and carried out by the author and members of the Office of Statistics of the Ministry of Agriculture in Bolivia in the months of June and July in 1972. The Utah State University Team also participated with its Bolivian personnel and economic assistance.

The production survey was carried out using a two-stage sampling process. All small villages and communities were enumerated, and constituted the primary sampling units. Whenever a village or community had a number of families well above 20, it was broken down into two or more primary sampling units so as to come as close as possible to having 20 families in each primary unit. The primary units to be sampled were selected at random from the primary unit to be interviewed. The results of this survey were processed by the Office of Statistics of the Ministry of Agriculture and published in 1973.

The costs-of-production survey was collected with the aid of the extension agents of the area and personnel from the Office of Statistics of the Ministry of Agriculture. The total number of questionnaires was 233, distributed mainly among the seven most important crops (included in the model), and four types of land-clearing methods. An effort was made to obtain equal numbers of questionnaires from the different sizes of farms to account for possible cost and/or yield differences due to the scale of farming. The results of this survey were processed in detail by the author and a description of the procedure used as well as the results obtained appear in Appendix A.

Outline

Chapter II explains the procedure followed to obtain the estimated input/output coefficients, prices, and constraints used in the linear programming equations.

The land allocation that maximizes net returns to the agricultural sector under the prices that existed before the devaluation is examined in Chapter III; the supply curves for each crop are also estimated, as well as the effects of changes in labor wages.

The effect of the currency devaluation and the domestic price inflation that followed it are the topics of Chapter IV. The potential impact of an export tax on cotton and its effect on social welfare are assessed in Chapter V.

Chapter VI analyzes what size of government price subsidy would be required to reach self-sufficiency in wheat production. Estimates of the social cost of such government policy are made.

CHAPTER II

THE LINEAR PROGRAM

The purpose of this Chapter is to explain how the objective function and constraints associated with the linear programming problem were derived. It begins by stating how the left-hand side (LHS) coefficients (product and factor ratios, and prices) were obtained, following with the setting of land, labor, and production constraints, which are referred to as the right-hand side (RHS) coefficients.

The crops included in the analysis and which compete for the land presently in use are soybeans (summer-mechanized and manual, and winter-mechanized), winter wheat, corn, rice (mechanized and manual), cotton, sugar cane, and yuca.

Since cotton production has been increasing the past few years and capital is available, this crop not only can take land away from other crops, but also can pump resources into the clearing of new land. In order to assess the effects of this cotton development, three additional crops have been included in the program, and they only compete for the new land not yet cleared: cotton, soybeans, and wheat. These last two are potential winter crops. The amount of fertilizer needed to maintain the soil if these crops are planted every year has been estimated at four bags per hectare (46 to 50 kg. per bag), and the fertilizer cost is assumed to be shared equally by the winter and summer crops.[12]

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[12] Interview with Dr. George Hargreaves, Department of Agricultural Engineering, Utah State University.

It has been widely speculated that wheat production in the area could be the solution to the chronic deficit in national wheat production that requires about 15 million dollars (US) in imports required to cover the domestic demand every year. It has been assumed in this study that wheat as a winter crop can be double-cropped either with cotton or soybeans, with an average yield of 20 cwt per hectare. (Questions have been raised with regards to the technical feasibility of double-cropping cotton and wheat in land without irrigation. Farmers are reluctant to shift the planting season of cotton forward to allow for wheat planting before the rainy season is over so that a minimum of humidity is available to wheat seeds at the initial stages of growth. At the time of the survey in 1972, irrigation was being introduced in the area on a very limited scale and no reliable data were available on the expected yields with irrigation. The introduction of irrigation on a significant proportion of the agricultural land would obviously alter the pattern of land allocation, but it has not been included in the model because of the lack of data.

Input and Output Coefficients in the Production Functions

Production coefficients were estimated from questionnaire survey data (see Appendix A). These coefficients were calculated for six time periods of two months each (see Tables 85 and 86, Appendix B) so that the input requirements (labor, tractors, combines, etc.) could be estimated for each period of time, and for each operation in the production of every crop.

Since the analysis is concerned with the short run effects of prices, taxes, etc., upon the optimum land allocation, all input requirements which are a given quantity per hectare become fixed costs, and those that depend on the quantity produced per hectare are variable costs. All other expenditures such as land clearing costs or other improvements on the land were ignored throughout the analysis. To escape the problems of estimating factors such as depreciation and repairs of machinery (good data were not available), custom rates were estimated whenever such machinery was utilized. In the case of tractors and combines, these custom rates include the wages paid to the driver and one assistant, the typical pattern of operation.

These custom rates have been estimated at $b 74.83 per machine-hour (MH) for tractors (Table 78, Appendix A), and $b 256.50/MH for bulldozer operation (Table 57, Appendix A). With regards to harvesting combines, the results of the survey indicated 1.60 MH/hectare for wheat harvesting, with a cost of $b 215.25/hectare. The implied hourly rate would, therefore, be 215.25/1.6 = 134.53 $b/MH.

Once the labor costs were deducted, the actual cost coefficients used in the program became 71.33, 253.0, and 131.03 respectively. Regular wages for two persons, namely the driver and one assistant were deducted at the rate of $b 14.0/man-day each, that is $b 3.50/hour on each operation for an average of 8 hours per work day.

Tables 5 to 17 show the input requirements for each operation for all crops. Unless otherwise specified, these data have been calculated applying the time distribution coefficients from Table 86, Appendix B to the production coefficients.

Table 5. Input requirements for summer mechanized soybeans, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MH)	.90	1.50	.60	----	---	--	3.00[a]
Seeding	(MH)	---	0.38	.57	----	---	--	0.95[b]
Seed ($b 67.17/cwt)[c]	(cwt)							0.93[c]
Weeding (2 times)	(MH)	---	1.00	2.00	1.00	---	--	4.00[a]
Spraying (2 times)	(MH)	---	0.20	0.50	0.30	---	--	1.00[a]
Chemicals	($b)							89.00[a]
Harvesting combine	(MH)	---	----	----	0.56	.24	--	0.80[d]
Total tractor	(MH)	.90	3.08	3.67	1.30	---	--	8.95
Total combine	(MH)	---	----	----	0.56	.24	--	0.80
Variable factors per cwt.								
Handling and loading	(MD)	---	----	----	0.07	.03	--	0.10[e]
Transport to market	($b)							4.00[c]
Total	(MD)	---	----	----	0.07	.03	--	0.10

Yield 35.0 cwt. per hectare[f]
Price 58.20 $b/cwt[c]

[a]Production budgets, San Juan colony experiment station, 1972. Unpublished.

[b]Table 62, Appendix A.

[c]Table 67, Appendix .

[d]Utah State University/Usaid/Bolivia, Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia, USU Series 13/72, July 1972, p. 141.

[e]Calculated from: $b 1.45 per cwt/$b 14 per MD = 0.10 MD/cwt. (See Table 67, Appendix A.)

[f]Table 19.

Table 6. Input requirements for summer hand soybeans, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MD)	----	----	--	3.90	6.50	2.60	13.00[a]
Seeding	(MD)	----	----	--	----	2.40	1.60	4.00[b]
Seed ($b 67.17/cwt)[b]	(cwt)							0.93[b]
First weeding	(MD)	1.60	----	--	----	2.40	4.00	8.00[b]
Second weeding	(MD)	2.40	----	--	----	1.60	4.00	8.00[b]
Third weeding	(MD)	3.20	----	--	----	1.60	3.20	8.00[b]
Harvesting	(MD)	8.75	3.75	--	----	----	----	12.50[b]
Total man-days	(MD)	15.95	3.75	--	3.90	14.50	15.40	53.50
Variable factors per cwt.								
Threshing and handling	(MD)	0.23	0.10	--	----	----	----	0.33[b]
Transport to market	($b)							4.00[b]
Total man-days	(MD)	0.23	0.10	--	----	----	----	0.33

Yield 26.17 cwt. per hectare[b]
Price 58.20 $b/cwt[b]

[a]From Table 62, Appendix A. (It is only 5.0 MD/hectare in the San Juan colony budgets.)

[b]From Table 67, Appendix A.

Table 7. Input requirements for winter mechanized soybeans in newly cleared land, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MH)	----	---	--	.90	1.50	0.60	3.00
Seeding	(MH)	----	---	--	---	0.57	0.38	0.95
Seed ($b 67.17/cwt)	(cwt)							0.93
Weeding (2 times)	(MH)	1.00	---	--	---	1.00	2.00	4.00
Spraying (2 times)	(MH)	0.30	---	--	---	0.20	0.50	1.00
Chemicals	($b)							89.00
Fertilizer ($b 60/cwt)[a]	(cwt)							2.00[b]
Harvesting combine	(MH)	0.56	.24	--	---	----	----	0.80
Total tractor	(MH)	1.30	---	--	.90	3.27	3.48	8.95
Total combine	(MH)	0.56	.24	--	---	----	----	0.80
Variable factors per cwt.								
Handling and loading	(MD)	0.07	.03	--	---	----	----	0.10
Transport to market	($b)							4.00
Total man-days	(MD)	0.07	.03	--	---	----	----	0.10

Yield 26.25 cwt/hectare[c]
Price 58.20 $b/hectare

Source: Table 5.

[a]Utah State University/Usaid/Bolivia, Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia, USU Series 13/72, July 1972, p. 198.

[b]From an interview with Dr. George Hargreaves, Department of Agricultural Engineering, Utah State University, it was estimated that about 4 bags of fertilizer would be required to maintain soil fertility. This requirement has been split between the summer and the winter crop.

[c]From Table 19.

Table 8. Input requirements for winter mechanized soybeans, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land prepartion	(MH)	----	---	--	.90	1.50	0.60	3.00
Seeding	(MH)	----	---	--	---	0.57	0.38	0.95
Sedd ($b 67.17/cwt)	(cwt)							0.93
Weeding (2 times)	(MH)	1.00	---	--	---	1.00	2.00	4.00
Spraying (2 times)	(MH)	0.30	---	--	---	0.20	0.50	1.00
Chemicals	($b)							89.00
Harvesting combine	(MH)	0.56	.24	--	---	----	----	0.80
Total tractor	(MH)	1.30	---			3.27	3.48	8.95
Total combine	(MH)	0.56	.24	--	---	----	----	0.80
Variable factors per cwt.								
Handling and loading	(MD)	0.07	.03	--	---	----	----	0.10
Transport to market	($b)							4.00
Total man-days	(MD)	0.07	.03	--	---	----	----	0.10

Yield 26.25 cwt/hectare
Price $b 58.20 per cwt.

Source: Table 7.

Table 9. Input requirements for winter wheat, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MD)	3.90	6.50	2.60	---	---	--	13.00[a]
Seeding	(MH)	----	0.38	0.57	---	---	--	0.95[a]
Seed ($b 78.2/cwt)[a]	(cwt)							1.82[a]
Spraying (2 times)	(MH)	----	0.30	0.50	.20	---	--	1.00[b]
Chemicals	($b)							89.00[b]
Harvesting combine	(MH)	----	----	---	.49	.21	--	0.70[c]
Total man-days	(MD)	3.90	6.50	2.60	---	---	--	13.00
Total tractor	(MH)	----	0.68	1.07	.20	---	--	1.95
Total combine	(MH)	----	----	---	.49	.21	--	0.70
Variable factors per cwt.								
Transport to market	($b)							1.82[a]
Bags	($b)							0.72[d]

Yield 20.00 cwt/hectare
Price $b 46.75 per cwt.

[a]From Table 62, Appendix A.

[b]From Table 5; it is assumed to be the same for wheat and soybeans.

[c]Utah State University/Usaid/Bolivia, Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia, USU Series 13/72, July 1972, p. 148.

[d]From Table 64, Appendix A.

Table 10. Input requirements for winter wheat in newly cleared land, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MD)	3.90	6.50	2.60	---	---	--	13.00
Seeding	(MH)	----	0.38	0.57	---	---	--	0.95
Seed ($b 78.2/cwt)	(cwt)							1.82
Spraying (2 times)	(MH)	----	0.30	0.50	.20	---	--	1.00
Chemicals	($b)							89.00
Fertilizer ($b 60/cwt)[a]	(cwt)							2.00[a]
Harvesting combine	(MH)	----	----	---	.49	.21	--	0.70
Total man-days	(MD)	3.90	6.50	2.60	---	---	--	13.00
Total tractor	(MH)	----	0.68	1.07	.20	---	--	1.95
Total combine	(MH)	----	----	----	.49	.21	--	0.70
Variable factors per cwt.								
Transport to market	($b)							1.82
Bags	($b)							0.72

Yield 20.00 cwt/hectare
Price $b 46.75 per cwt.

Source: Table 9.

[a]From Table 7.

Table 11. Input requirements for cotton, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MH)	----	----	0.11	0.71	3.75	0.86	5.43[a]
Seeding	(MH)	0.01	----	----	0.05	0.55	0.11	0.72[a]
Seed ($b 7.38/lb)[a]	(lb)							27.95[a]
Thinning	(MD)	0.04	0.04	0.04	0.12	1.28	2.48	4.00[a]
Hand weeding	(MD)	3.28	3.28	0.63	0.39	2.65	5.39	15.62[b]
Tractor weeding	(MH)	0.80	0.26	0.05	0.04	0.13	0.53	1.81[c]
Aerial spraying (10 times)	($b)							150.00[d]
Chemicals	($b)							357.00[d]
Plowing	(MH)	0.18	1.47	1.08	0.27	----	----	3.00[e]
Total man-days	(MD)	3.32	3.32	0.67	0.51	3.93	7.87	19.62
Total tractor	(MH)	0.99	1.73	1.24	1.07	4.43	1.50	10.96
Variable factors per cwt.								
Harvesting	(MD)	----	1.43	1.90	----	----	----	3.33[f]
Ginning	($b)							35.00[a]
Transport to ginner	($b)							2.39[a]
Total man-days	(MD)	----	1.43	1.90	----	----	----	3.33

Yield 12.85 cwt/hectare[a]
Price $b 350.0 per cwt.[g]

[a]From Table 63, Appendix A.

[b]From Table 63, Appendix A: 2.64 times, 11.83 MD/hectare each, means 31.24 MD/hectare, or $b 437.36/hectare, at $b 14/MD. But since it is estimated at only $b 240/hectare at Utah State University/Usaid/Bolivia, Irrigation Study for Selected Crops, Santa Cruz, Bolivia, USU Series 13/72, July 1972, p. 203, and at $b 200/hectare by W. Augusto Parra, "El Cultivo del Algodón en el area de Santa Cruz y sus Necesidades de Capital para el Periodo 1972/73," p. 26 , the first estimate has been arbitrarily reduced to one half.

[c]An average of 2.11 times, 0.86 MH/hectare each. (Table 63, Appendix A.)

Table 11. Continued

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[d]W. Augusto Parra, "El Cultivo del Algodón en el area de Santa Cruz y sus Necesidades de Capital para el Periodo 1972/73," p. 26.

[e]Production budgets, Okinawa colony, Santa Cruz. Unpublished.

[f]From Table 63, Appendix A: it is $b 15.5/cwt for the second harvesting. At $b 14/MD it means 1.11 MD/cwt of raw cotton or 3.33 MD/cwt of ginned cotton.

[g]Utah State University/Usaid/Bolivia, Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia, USU Series 13/72, July 1972, p. 201.

Table 12. Input requirements for cotton in newly cleared land, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land clearing:								
bulldozer	(MH)	0.128	0.128	0.128	0.128	0.128	0.128	0.768[a]
tractor	(MH)	0.12	0.12	0.12	0.12	0.12	0.12	0.72[a]
Land preparation	(MH)	----	----	0.11	0.71	3.75	0.86	5.43
Seeding	(MH)	0.01	----	----	0.05	0.55	0.11	0.72
Seed ($b 7.38/lb)	(lb)							27.95
Thinning	(MD)	0.04	0.04	0.04	0.12	1.28	2.48	4.00
Hand weeding	(MD)	3.28	3.28	0.63	0.39	2.65	5.39	15.62
Tractor weeding	(MH)	0.80	0.26	0.05	0.04	0.13	0.53	1.81
Aerial spraying (10 times)	($b)							150.00
Chemicals	($b)							357.00
Fertilizer ($b 60/cwt)[b]	(cwt)							2.00[b]
Plowing	(MH)	0.18	1.47	1.08	0.27	----	----	3.00
Total bulldozer	(MH)	0.128	0.128	0.128	0.128	0.128	0.128	0.768
Total tractor	(MH)	1.11	1.85	1.36	1.19	4.55	1.62	11.68
Total man-days	(MD)	3.32	3.32	0.67	0.51	3.93	7.87	19.62
Variable factors per cwt.								
Harvesting	(MD)	----	1.43	1.90	----	----	----	3.33
Ginning	($b)							35.00
Transport to ginner	($b)							2.39
Total man-days	(MD)	----	1.43	1.90	----	----	----	3.33

Yield 12.85 cwt/hectare
Price $b 350.0/cwt

Source: Table 11.

[a]From Table 57, Appendix A: land clearing costs of 5.12 MH of bulldozer, and 4.77 MH of tractor amortized at 15 percent and spread over the entire year.

[b]From Table 7.

Table 13. Input requirements for corn, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MD)	----	----	----	4.60	7.66	3.07	15.33[a]
Seeding	(MD)	0.36	----	----	----	1.82	1.07	3.25[a]
Seed ($b 28.44/cwt)[a]	(cwt)							0.33[a]
First weeding	(MD)	1.51	----	----	----	2.14	5.26	8.91[a]
Second weeding	(MD)	1.03	1.02	----	----	----	2.06	4.11[b]
Harvesting	(MD)	4.86	2.43	2.42	----	----	----	9.71[a]
Total man-days	(MD)	7.76	3.45	2.42	4.60	11.62	11.46	41.31
Variable factors per cwt.								
Shelling	(MD)	0.02	0.02	0.02	0.02	0.02	0.01	0.11[a]
Handling and loading	(MD)	0.03	0.03	0.03	0.02	0.02	0.03	0.16[a]
Bags	($b)							0.78[a]
Transport to market	($b)							2.66[a]
Total man-days	(MD)	0.05	0.05	0.05	0.04	0.04	0.04	0.27
Yield[c]								
Price $b 21.18/cwt.[a]								

[a]From Table 65, Appendix A.

[b]From Table 65, Appendix A: the estimate is 7.90 MD/hectare, but only 52 percent of the farmers reported a second weeding.

[c]Since mechanized corn production is fairly uncommon, the average yields of Table 18 were used, and the mechanized method was ignored.

Table 14. Input requirements for mechanized rice, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MH)	0.06	----	0.03	0.27	1.89	0.75	3.00[a]
Seeding	(MH)	0.06	----	----	0.04	0.38	0.52	1.00[a]
Seed ($b 53.92/cwt)[b]	(lb)							55.21[b]
Weeding	(MH)	0.96	0.16	0.04	0.08	0.60	2.16	4.00[a]
Spraying (3 times)	(MH)	0.73	0.08	0.01	0.01	0.12	0.55	1.50[a]
Chemicals	($b)							218.50[a]
Harvesting combine	(MH)	0.14	0.77	0.09	----	----	----	1.00[a]
Total tractor	(MH)	1.81	0.24	0.08	0.40	2.99	3.98	9.50
Total combine	(MH)	0.14	0.77	0.09	----	----	----	1.00
Variable factors per cwt.								
Drying and handling	(MD)	0.01	0.08	0.07	0.01	----	----	0.17[b]
Milling	($b)							1.66[b]
Transport to mill	($b)							2.13[b]
Bags	($b)							0.72[b]
Membership fees	($b)							0.24[b]
Total man-days	(MD)	0.01	0.08	0.07	0.01	----	----	0.17
Yield[c]								
Price $b 48.23/cwt.[d]								

[a]Production budgets, San Juan colony experiment station, Santa Cruz, 1972. Unpublished.

[b]From Table 64, Appendix A.

[c] See Table 18.

[d]The milled rice price is estimated at $b 68.90/cwt, therefore, the "equivalent rough rice" price would be 68.9 x 0.70 = 48.23 $b/cwt, which must be used since both yields as well as variable factors refer to units of rough rice.

Table 15. Input requirements for hand rice, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MD)	0.24	----	0.12	1.08	7.56	3.00	12.00[a]
Seeding	(MD)	0.13	----	----	0.08	0.78	1.07	2.06[a]
Seed ($b 53.92/cwt)[a]	(lb)							55.21[a]
Hand seeder rent	($b)							32.00[a]
First weeding	(MD)	2.13	0.36	0.09	0.18	1.33	4.80	8.89[a]
Second weeding	(MD)	5.92	0.49	0.08	----	0.08	1.54	8.11[a]
Total man-days	(MD)	8.42	0.85	0.29	1.34	9.75	10.41	31.06
Variable factors per cwt.								
Harvesting	(MD)	0.10	0.56	0.08	----	----	----	0.74[b]
Drying and handling	(MD)	0.01	0.08	0.07	0.01	----	----	0.17[a]
Milling	($b)							1.66[a]
Transport to mill	($b)							2.13[a]
Bags	($b)							0.72[a]
Membership fees	($b)							0.24[a]
Total man-days	(MD)	0.11	0.64	0.15	0.01	----	----	0.91
Yield[c]								
Price $b 48.23/cwt.[d]								

[a]From Table 64, Appendix A.

[b]From Table 64, Appendix A: it is estimated at 38.5 MD per hectare, with a yield of 51.92 cwt per hectare.

[c]See Table 18.

[d]From Table 14.

Table 16. Input requirements for yuca, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MD)	0.26	1.17	6.24	2.99	1.82	0.52	13.00[a]
Seeding	(MD)	0.13	0.53	2.80	5.85	3.19	0.80	13.30[a]
Seed treatment	(MD)	0.02	0.07	0.37	0.78	0.42	0.11	1.77[a]
Seed ($b 4.94/cwt)	(cwt)							8.44[a]
First weeding	(MD)	1.78	1.78	1.78	1.78	1.79	1.79	10.70[a]
Second weeding	(MD)	1.63	1.63	1.63	1.63	1.63	1.63	9.78[a]
Third weeding	(MD)	0.83	0.83	0.83	0.84	0.84	0.83	5.00[b]
Harvesting	(MD)	5.42	5.41	5.41	5.42	5.42	5.42	32.50[a]
Total man-days	(MD)	10.07	11.42	19.06	19.29	15.11	11.10	86.05
Variable factors per cwt.								
Handling and loading	(MD)	.005	.005	.005	.005	.005	.005	0.03[a]
Transport to market	($b)							3.40[a]
Total man-days	(MD)	.005	.005	.005	.005	.005	.005	0.03

Yield 359.33 cwt/hectare[a]
Price $b 8.985/cwt.[c]

[a]From Table 66, Appendix A.

[b]In Table 66, Appendix A it is estimated at 10 MD/hectare, but only 50 percent of the farmers interviewed did it.

[c]The estimated price of $b 11.98/cwt (Table 66, Appendix A), with 359.33 cwt/hectare does not make allowance for losses and inferior quality non-marketable product. A 25 percent reduction, to $b 8.985/cwt has been arbitrarily applied to account for that.

Table 17. Input requirements for sugar cane, per hectare

Fixed factors per hectare	Units	Period 1	2	3	4	5	6	Total
Land preparation	(MD)	0.04	0.10	0.42	0.69	0.38	0.10	1.73[a]
Planting	(MD)	0.08	0.03	0.13	0.65	1.35	0.46	2.70[a]
Seed ($b 42.21/MT)[b]	(MT)							0.56[a]
First weeding	(MD)	0.61	0.10	0.31	1.62	4.56	2.94	10.14[b]
Second weeding	(MD)	1.90	0.50	0.20	0.70	2.60	4.10	10.00[b]
Third weeding	(MD)	1.44	0.38	0.15	0.53	1.98	3.11	7.59[c]
Total man-days	(MD)	4.07	1.11	1.21	4.19	10.87	10.71	32.16
Variable factors per metric ton[f]								
Harvesting	(MD)							1.08[d]
Membership fees	($b)							2.26[b]
Yield[e]								
Price $b 70.65/metric ton.								

[a]The actual estimates on Table 61 Appendix A are 14.33 MD/hectare, 22.29 MD/hectare, and 4.66 MT/hectare, they have been spread over the average number of years of production.

[b]From Table 61, Appendix A.

[c]The estimate is 10.4 MD/hectare (Table 61, Appendix A), but only 73 percent of the interviewed farmers did it.

[d]Calculated with $b 15.12/MT (Table 61, Appendix A), and $b 14/man-day. No time distribution is given since the program does not use it in this case.

[e]See Table 18.

[f]Transport costs are in Table 88, Appendix C.

Per hectare yields

In order to obtain a quantitative model that describes the actual situation as closely as possible, whenever the availability of data permitted it, regional yield differences were introduced into the system.

The Office of Statistics of the Ministry of Agriculture has published the results of its production survey. During this survey, interviews were held with farmers selected by means of random sampling techniques. Per hectare yields have been estimated for rice, corn, and sugar cane for each one of the five provinces in the study area of the Department of Santa Cruz. Table 18 shows a summary of the results. There are yield differences due to the land clearing method used, the reason being that hand clearing methods (*chaqueado a mano*, *barbecho*) do not usually remove tree stumps and thus it is impossible to cultivate the land with tractors. Machine land clearing methods (*desmonte*, *arado en pampa*) include plowing and levelling the soil.

As Table 18 indicates, most of the land devoted to corn, rice, and sugar cane production has been cleared using hand methods while most of the land cleared by machinery is devoted to cotton production.

Additional information was obtained from an annual survey of farmers in the San Juan colony. The survey was made by the technicians working in the experiment station that functions in the colony. This provided information on the input requirements for the production of rice and soybeans, as well as average yields using the more advanced techniques that include tractors for land preparation, seeding, weeding, etc. (see Tables 5 and 14).

Table 18. Average expected yields of corn, rice, and sugar cane, per province and method of production, per hectare

Corn	Units	Provincia: Santis-teban	Sara	Warnes	Ibáñez	Ichilo	Average	Percent of the land
Mechanized	(cwt)	-----	48.18	-----	40.48	-----	42.90	7
Hand	(cwt)	48.40	39.82	46.64	42.02	49.94	45.10	93
Average	(cwt)	48.40	41.58	46.64	41.80	49.94	44.88	100
Rice								
Mechanized	(cwt)	53.46	35.64	41.80	-----	32.78	36.52	4
Hand	(cwt)	41.58	40.70	34.54	37.40	40.26	40.48	96
Average	(cwt)	41.80	40.48	34.54	37.40	39.82	40.26	100
Sugar cane								
Hand	(MT)	41.00	28.90	31.30	31.50	42.80	36.60	100

Source: Production survey, Ministry of Agriculture, Bolivia, 1972.

Since no data on mechanized soybeans production were obtained in the costs of production survey, it was necessary to secure additional data with information on yields and input requirements.

The production budget obtained from the experiment station at the San Juan colony used a yield estimate for mechanized soybeans of 39.6 cwt/hectare. The USU irrigation study assumed a 25 cwt/hectare yield.[13] It appears that the 39.6 estimate is too high compared with the yield obtained for hand production in the survey (26.15 cwt per hectare), and the 25.0 cwt per hectare figure. Therefore, a compromise was

[13] Utah State University/Usaid/Bolivia, <u>Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia</u>, USU Series 13/72, July 1972, p. 195.

Table 19. Average expected yields, per hectare

Crop	Yield cwt
Yuca	359.33[a]
Cotton	12.85[b]
Wheat	20.00[c]
Summer hand soybeans	26.17[d]
Summer mechanized soybeans	35.00
Winter mechanized soybeans	26.25

[a]From Table 66 , Appendix A.

[b]From Table 63, Appendix A.

[c]Utah State University/Usaid/Bolivia, Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia, USU Series 13/72, July 1972, p. 205.

[d]From Table 67 , Appendix A.

arbitrarily set at 35.0 cwt per hectare.[14] It was also assumed that winter yields would be 25 percent lower; that is, 26.25 cwt per hectare.

Daily wages

Following the results obtained in Table 77, Appendix A, two different wage levels were introduced in the analysis. All wages paid

[14]In drawing this compromise estimate more confidence is being placed on the 39.6 cwt per hectare figure because it is supposed to be the actual value obtained in the colony while the 25.0 cwt per hectare estimate was obtained from secondary sources and the relatively more reliable estimate of 26.17 cwt per hectare refers to hand production.

for cotton, sugar cane, and soybeans production were $b 14.00 per man-day while wages paid to rice, wheat, corn, and yuca production were $b 12.85 per man-day.

Both cotton and sugar cane are centered around the towns of Portachuelo, Montero, and Warnes. These are the lands formerly producing rice, and which have been gradually shifted first into sugar cane production and then into cotton. Most of the land in this area has been previously used in agriculture apparently without any effort being made to maintain the fertility of the soils by means of the application of either chemical or organic fertilizers. However, this is not yet a physical constraint on cotton production since it can be successfully farmed in less fertile soils than those required for sugar cane. This factor, coupled with higher world cotton prices has tended to shift sugar cane production into new areas, particularly north of Mineros in the province of Santisteban. Nevertheless, this movement of sugar cane production into new areas is constrained by the higher transportation costs which can be as high as 50 percent of the total costs of production.

The result is that while cotton and sugar cane are being produced in the vicinity of the larger towns and the roads between them, the other crops: rice, corn, and yuca, are being introduced into areas with more difficult access.[15]

Location is probably the determining factor that explains why agricultural wages for cotton, sugar cane, and soybeans appear to be higher than wages paid in the production of rice, corn, and yuca.

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[15] Cotton production cannot move further north because of rains in excess of 1,500 mm per year.

Labor is drawn from the peripheral newly colonized areas into the central region for the cultivation of sugar cane, soybeans, and cotton.[16] In order to compensate these laborers for the added expenses which they incur when they go away from their farms, higher wages must be paid in comparison with those paid for the same type of services in the "frontier" areas where a much lower proportion of the land is devoted to sugar cane, soybeans, and cotton production.

Transportation

Since most of the farmers provide their own seeds, except in the case of cotton, seed prices quoted are those at the farm level and no transport requirements have been included. Prices of all other factors of production are also at the farm level.

Transportation costs are not the same for every crop, not merely because they are produced in different areas, but mainly because they are not marketed through the same channels. Sugar cane is taken to one of the three mills available (Guabirá, La Bélgica, and San Aurelio). Rice is generally sold at the mills which are located mainly in the vicinity of Portachuelo. In 1971, there were 213 mills in the Department and some new mills are now being built even in the colonization areas.[17] Cotton is taken to the processing plants near Santa Cruz to be ginned before it is available for sale. It has been assumed that wheat is marketed in the city of Santa Cruz, although if no flour mills are built

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[16] A survey of these areas indicated that an average of 64 percent of the farms hire labor. Therefore, there is a labor pool which is available to go to the other areas at certain periods of time.

[17] Kenneth L. Graber, Agricultural Life in the Colonies, An Economic Study of Ten Colonies North of Santa Cruz Bolivia, Rural Work Committee, Eastern District, Methodist Church in Bolivia, May 1972, p. 12.

there, it will have to continue being transported to Cochabamba. Since yuca is mostly used for domestic consumption, during the interviews only a few farmers were able to quote market prices and transportation costs to the city of Santa Cruz. The market for soybeans has not been developed to a great extent, but prices and transport costs have been estimated assuming that the product is marketed in Santa Cruz, since if an oil mill is construed it will likely be there.

Since transportation covers about 50 percent of the total costs of production for sugar cane, a more detailed procedure was used to estimate the transportation costs. Using the data published by the USU study team, average sugar cane transportation costs were estimated for each one of the five provinces.[18] It was assumed that the least-cost transportation model was the one that applied. This assumption does not seem too heroic since the total transportation costs in the least cost model have been estimated to be only 3.2 percent below the current transport costs, but even so are probably the best estimate of future costs.

Table 87, Appendix C shows 54 sugar cane producing areas classified by province. Total transport costs and total amount delivered were calculated for each province. The average transportation costs estimated are shown in Table 88, Appendix C.

Operating capital

The annual interest rate charged by the government bank for short term loans was and is 18 percent, but in the presence of inflation, the

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[18]Boyd Wennergren, et al., Irrigation and Non-irrigation Alternatives for Reducing Sugar Cane Transportation Costs in Santa Cruz, Bolivia, Utah State University, Department of Economics, Cusuwash, June 1973, pp. 22-23.

actual real rate paid for loans is surely below 18 percent. On the other hand, a few years ago the same bank charged a 12 percent interest rate on loans to agricultural producers, but this lower rate was subsidized by the government and no significant price inflation existed at that time. An estimate of the opportunity cost of capital used in agriculture would be somewhere below 18 percent, but above 12 percent. A 15 percent estimate is commonly accepted, has been adopted by other researchers, and is assumed in this study.[19]

A simplifying assumption is that all operating costs are evenly spread over the production period initiated with the land preparation operations and completed with the sale of the product.

It is estimated that the time necessary for the production cycle is about 6 months for corn, soybeans, and wheat. The figure for cotton and rice is 8 months since they require some additional time for milling. The remaining crops, yuca, and sugar cane take up the entire year.

Input and Output Equations in the Model

Rather than listing all of the equations included one by one, they will be described summarily, indicating only the type of equations used for one of the crops. The equations are practically the same for all the crops.

The first equation is:

$$- Q + \Sigma_i \; y_i \; L_i = 0$$

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[19]The same rate has been used in: Utah State University/Usaid/ Bolivia, Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia, USU Series 13/72, p. 131.

where: Q : quantity of the crop produced.

y_i : expected average per hectare yield in the i^{th} province

L_i : number of hectares allocated to the crop in the i^{th} province.

In order to discover the total land allocated to the crop, the land per province is added to calculate the total:

$$\sum_i L_i - L = 0$$

where: L : total number of hectares allocated to the crop.

The input factors are entered in the following manner:

$$a_{ij} Q + b_{ij} L - I_{ij} = 0$$

where:

a_{ij} : amount of the i^{th} input required per unit of the product in the j^{th} time period.

b_{ij} : amount of the i^{th} input required per hectare in the j^{th} time period.

I_{ij} : quantity of the i^{th} input required in the j^{th} time period.

In order to enter these input costs into the objective function, they are first totaled since they have the same costs over all the time periods:

$$\sum_j I_{ij} - I_i = 0$$

where: I_i : total quantity required of the i^{th} input.

Since a minimization procedure was followed, the profits are entered with negative signs in the objective function while the costs appear with positive signs as follows:

$$-pQ + \sum_i C_i I_i$$

where p : per unit expected price of the product.

c_i : per unit expected cost of the i^{th} input.

Land Constraints

Present total land availability

Table 20 shows the estimates for the total land area planted in each of the major crops in each province in 1971-72. These estimates are used to establish the maximum constraints of cleared land available for all crops, and are expressed in the first twenty land constraint equations.

Present cotton land availability

No physiological or climatic impediment exists to switching all crop land into cotton production with the exception of the area in the Ichilo province where excessive rain and humidity would damage cotton. No exact quantitative data are available, so it has been estimated that only 10 percent of the land devoted to other crops in Ichilo can be turned into cotton production. All the land in the other provinces could be put into cotton.

There are other considerations besides soil and climate, however, that might prevent cotton production. Clearly, cotton cannot be produced in very small plots, mainly because it is sprayed by airplanes, and it is not feasible to spray small plots by air. The airplane pilots are reluctant to work on small plots of land due to the added risk and work involved. Consequently, the spraying of the smaller fields is frequently delayed with negative impact on cotton yields. It has been assumed, therefore, that a cotton field should be at least 50 hectares in size.

Table 20. Estimates of land use by province and crop, 1971-72

Crop	Province					Total
	Santisteban	Sara	Warnes	Ibáñez	Ichilo	
Corn[a]	7,800	4,350	4,690	10,170	2,500	29,510
Rice[a]	6,255	7,921	1,041	205	19,170	34,592
Sugar cane[a]	19,405	1,968	8,674	4,909	545	35,501
Yuca[b]	650	1,400	1,200	719	2,500	6,469
Soybeans[b]	1,800	------	------	------	------	1,800
Total	35,910	15,639	15,605	16,003	24,715	107,872
Cotton[c]	17,784	4,053	17,211	7,571	961	47,580
Total	53,694	19,692	32,816	23,574	25,676	155,452

[a]From the Ministry of Agriculture survey, 1971-72.

[b]Federación Departamental de Empresarios Privados, Santa Cruz-Bolivia. Estadísticas Económicas y Sociales del Departamento de Santa Cruz. March, 1972. p. 41.

[c]W. Augusto Parra, "El Cultivo del Algodón en el Area de Santa Cruz y sus Necesidades de Capital para el Periodo 1972-73," p. 3.

Because of the fact that about 50 percent of the land is of marginal quality or is in rivers, roads, houses, and fruit trees around them, etc., the minimum size of farm should be about 100 hectares in order to produce cotton.

Table 21 presents a stratification of farms by size obtained from Ministry of Agriculture survey made in all the rice production areas in 1971. It is reasonable to assume that this stratification is still

Table 21. Scale of land ownership

Scale hectares	Total hectares	Per cent	Accumulative total hectares	Accumulative per cent
$x \leq 5$	5,073	0.80	5,073	0.80
$5 < x \leq 10$	4,943	0.78	10,016	1.58
$10 < x \leq 15$	9,642	1.52	19,658	3.11
$15 < x \leq 20$	12,513	1.98	32,171	5.08
$20 < x \leq 50$	135,626	21.42	167,797	26.51
$50 < x \leq 100$	170,226	26.89	338,023	53.39
$100 < x \leq 200$	56,717	8.96	394,740	62.35
$200 < x \leq 500$	51,996	8.21	446,736	70.57
$x < 500$	186,347	29.44	633,083	100.00

Source: Ministry of Agriculture survey on the rice producing areas in Santa Cruz, 1971.

valid as to the portion of cultivated land not yet switched into cotton production. The estimates on the maximum availability of cotton land appear in Table 22.

Present land availability for machine cultivated crops

Whether the land can be cultivated with machinery or not depends on the type of land clearing method used, since the presence of tree stumps and lack of land levelling on hand-cleared land would make cultivation impossible with tractors or harvesting with combines.

Table 22. Land availability for cotton, in hectares

	Province					
	Santisteban	Sara	Warnes	Ibañez	Ichilo	Total
All crops but cotton	35,910	15,639	15,605	16,003	24,715	107,872
Ichilo 10 per cent	35,910	15,639	15,605	16,003	2,471	85,628
Less than 100 hectares	16,738	7,289	7,273	7,459	1,152	39,911
Cotton land	17,784	4,053	17,211	7,571	961	47,580
Potential cotton land	34,522	11,342	24,484	15,030	2,113	87,491

The agricultural production survey conducted by the Ministry of Agriculture in 1971-72 for corn, rice, and sugar cane classifies the land according to the land clearing method used into five types: caterpillar tree clearing, plowing, continuous cropping, fallow, and hand clearing.

The first two methods assure complete clearing of all tree stumps and levelling of the land. The last two refer mostly to small plots with tree stumps, typical of the new colonized areas. The continuous cropping method could refer to either machine or hand cultivation. This class has been divided into two groups, each proportional to the hectarage appearing in the first two and the last two methods as a percentage of the total if the continuous cropping land is not included. It has been assumed that all land devoted to soybeans and cotton is free of tree stumps and can be mechanically cultivated. The results have been aggregated to obtain a total estimate of the land that can be mechanically cultivated by province (see Table 23).

Future total land availability

The only information on future land availability is the soil maps published by the British Mission in Santa Cruz.[20] By drawing the province limits on the soil maps, estimates were obtained of the total land availability and the potential cotton land in the five provinces (see Table 24). These estimates cover the land presently in use and the additional land where agricultural production is technically feasible once it is cleared. All land north of the northernmost colonization areas in the Ichilo and Santisteban provinces was ignored.

It is estimated that only about 50 percent of total land area actually available for agriculture. If the present amount of land in use is deducted, an estimate of the amount of land that might be cleared is obtained (Table 25).[21]

Land potential for cotton production

The total cotton land estimates from Table 24 are reduced by 50 percent because of the reasoning used above. Part of this land is presently being used for other crops besides cotton. It is estimated arbitrarily that only 10 percent of the land presently in other crops is

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[20] Thomas T. Cochrane, "A Land Systems Map of Central Tropical Bolivia," British Mission in Tropical Agriculture/Ministry of Agriculture, Reprint 1970.

[21] From an interview by the author and Dr. Allen LeBaron with Dr. Thomas T. Cochrane.

Table 23. Land availability for machine operated crops, in hectares

Crop	Province					Total
	Santisteban	Sara	Warnes	Ibáñez	Ichilo	
Corn[a]	33	364	4	1,488	---	1,889
Rice[a]	165	519	11	---	669	1,364
Sugar cane[a]	35	136	---	36	---	207
Soybeans[b]	1,800	---	---	---	---	1,800
Cotton[c]	17,784	4,053	17,211	7,571	961	47,580
Total	19,817	5,072	17,226	9.095	1,630	52,840

[a]Ministry of Agriculture production survey, 1971-72.

[b]Federación departamental de empresarios privados, Santa Cruz, Bolivia. "Estadísticas económicas y sociales del departamento de Santa Cruz," March 1972, p. 42.

[c]W. Augusto Parra, "El Cultivo del Algodón en el area de Santa Cruz y sus Necesidades de Capital para el Periodo 1972-73," p. 3.

Table 24. Land potential estimates, in hectares

Soil type[a]	Province					Total
	Santisteban	Sara	Warnes	Ibáñez	Ichilo	
2	---	6,000	---	80,000	20,000	106,000
20	---	---	38,000	7,000	---	45,000
1	---	---	---	90,500	138,000	228,400
28	---	---	---	---	18,000	18,000
27	---	8,000	---	---	120,000	128,000
26	---	38,000	---	---	13,000	51,000
3	---	32,000	---	---	---	32,000
21	114,000	---	114,000	195,000	---	423,000
22	15,000	---	63,000	28,000	---	106,000
23	43,000	---	---	---	---	43,000
Total	172,000	84,000	215,000	400,500	309,000	1,180,500
For cotton	172,000	70,000	215,000	230,000	13,000	700,000

[a]For a description of the soil type numbers see: Thomas T. Cochrane, "A Land Systems Map of Central Tropical Bolivia," British Mission in Tropical Agriculture/Ministerio de Asuntos Campesions y Agricultura, Reprint 1970.

actually occupying potential cotton land in the Ichilo province while the estimate rises to 100 percent in the other provinces. The reason is that a significant proportion of the agricultural land in the Ichilo province lies in the vicinity of the Yapacaní river and runs farther north towards Puerto Grether, where excessive rainfall and humidity are damaging to cotton production.

It is assumed that the type of ownership of the newly cleared land would be the same as that existent in the cultivated areas prior to the introduction of cotton production on a large scale. Since most of the small farms are owned by farmers that use traditional methods of production with limited access to credit sources, they are not likely to engage in buying additional land to enlarge the size of their farms and/or make significant investment in preparing the soil for mechanical cultivation of cotton, nor to sell their land to the larger and more prosperous farmers since it would probably leave the farmer and his family without work for a good portion of the year due to the seasonality of the labor requirements.

It was argued earlier that all farmers with less than 100 hectares would not enter into cotton production. Using the estimates obtained in Table 21, 53.39 percent of the land presently in other crops is assumed to remain out of cotton production (see Table 26).

Land Use

Taking the data on the percent of the operations undertaken in each period of the year for each crop (Table 86, Appendix B), estimates were made of the percent of land utilized for each crop at each period of the year (see Table 27).

Table 25. Estimates of the potential amount of land to be cleared, in hectares

	Province					
	Santisteban	Sara	Warnes	Ibáñez	Ichilo	Total
Total land potential	172,000	84,000	215,000	400,500	309,000	1,180,500
50 percent of total land	86,000	42,000	107,500	200,250	154,500	590,250
Present total land in use	53,694	19,692	32,816	23,574	25,676	155,452
Land to be cleared	32,306	22,308	74,684	176,676	128,824	434,798

Table 26. Estimates of the total potential for cotton land, in hectares

	Province					
	Santisteban	Sara	Warnes	Ibáñez	Ichilo	Total
Cotton land	172,000	70,000	215,000	230,000	13,000	700,000
50 percent of cotton land	86,000	35,000	107,500	115,000	6,500	350,000
Land presently in all crops but cotton	35,910	15,639	15,605	16,003	24,715	107,872
Ichilo 10 percent	35,910	15,639	15,605	16,003	2,471	85,628
53.39 percent $x \leq 100$ hectares	19,172	8,350	8,332	8,554	1,319	45,717
Total potential cotton land	66,828	26,650	99,168	106,456	5,181	304,283

Table 27. Land use coefficients

	Period					
Crop	1 January February	2 March April	3 May June	4 July August	5 September October	6 November December
Winter wheat	0.30	0.80	1.00	0.30	----	----
Corn	0.50	0.25	----	0.30	0.80	1.00
Yuca	1.00	1.00	1.00	1.00	1.00	1.00
Winter soybeans	0.30	0.80	1.00	0.30	----	----
Summer soybeans	0.30	----	----	0.30	0.80	1.00
Sugar cane	1.00	1.00	1.00	1.00	1.00	1.00
Cotton	0.91	0.31	0.05	0.15	0.84	1.00
Rice	0.86	0.10	0.02	0.10	0.73	0.97

Table 28. Availability of agricultural labor (1971)

	Persons
Total population in the department of Santa Cruz	548,939
City of Santa Cruz	130,892
Remainder, or rural population	418,047
Total population in the five provinces	334,355
Remainder, or rural population in the five provinces	334,355
Total agricultural labor force in the department	106,920
Estimated agricultural labor force in the five provinces	52,038

All of the coefficients in July and August (Table 27) are equal to or smaller than those of January and February, and all the coefficients in September and October are equal or smaller than those of November and December. Therefore, columns 4 and 5 will be ignored since all the constraints that could be established on land use for those two periods are already included in the other columns.

Land Constraints Equations

On the basis of the above, five sets of land constraints were introduced into the linear program. The first group consists of 20 constraints, four for each of the five provinces. It refers to the present land availability for all crops. Four constraints are required for each province because of the pattern of land use by time period as expressed in Table 27.

For example, the first land constraint is:

$$.3W + .5C + Y + .3Sw + .3Ss + Sc + .91\ Ct + .86R = 53{,}694$$

where

W = hectares in winter wheat, in province 1 (Santisteban)

C = hectares in corn, in province 1

Y = hectares in yuca, in province 1

Sw = hectares in winter soybeans, in province 1

Ss = hectares in summer soybeans, in province 1

Sc = hectares in sugar cane, in province 1

Ct = hectares in cotton, in province 1

R = hectares in rice, in province 1

The RHS coefficient is the total land estimate for province 1 (see Table 20, column 1). The coefficients for each of the crops are those of the first time period (column 1, Table 27). The three next equations will have the same RHS coefficient while the factors for each crop assume the values of columns 2, 3, and 6, of Table 27. The next set of four equations for province 2 (Sara) will have the same coefficients on the left hand side while the RHS coefficient assumes its respective value (19,692 hectares, Table 20), and so on.

Land constraints 21 through 25 refer to the maximum availability of cotton land presently in use. The constraints here introduced are those of Table 22.

The next set of land constraints equations, equal 26 through 45, sets the maximum constraints of land available for machine cultivated crops. They are: Winter soybeans, mechanized summer soybeans, cotton, mechanized rice, and winter wheat.

Five sets (one for each province) of equations, with four equations each are introduced in the manner just described for the first 20 land constraints. As a matter of fact, the factors on the LHS are still the same, although only the machine cultivated crops are considered, while the RHS constraint takes the values calculated in Table 23.

Land constraints 46 through 50 refer to the total available cotton land, including future land clearing. Consequently, an additional crop was introduced: cotton in newly cleared land, with the same characteristics as cotton on cleared land except for the additional expenditures on fertilizers and land clearing. The maximum constraints are listed in Table 26.

Land clearing costs per hectare include 5.12 machine-hours (MH) of caterpillar tree clearing and 4.77 MH of tractor operation for plowing and levelling (Table 57, Appendix A). These costs have been amortized at a 15 percent annual rate for reasons discussed earlier.

Wheat and soybeans are the two additional winter crops that are introduced in the analysis to be combined with cotton on the newly cleared land. Both carry an additional fertilizer cost, but no clearing costs are assigned to them.

The next 20 land constraints, number 51 through 70, refer to the available land to be cleared. The RHS coefficients are those calculated in Table 25.

Land constraints 71 through 75 are based on the figures estimated in Table 27 and refer to the double cropping of the newly cleared land.

Labor Constraints

Local labor

The adult male proportion of the population actively engaged in agriculture in all the Department of Santa Cruz was calculated to be 196,920/418,047 = 0.2558 (Table 28). No estimates were available of the rural population as such, but rough estimates were obtained by deducting the population of the city of Santa Cruz from the figures of total population.

Applying the 0.2558 factor on the estimate of the rural population in the five provinces, their labor forces in agriculture were estimated to be 52,038 persons (Table 28). By proceeding in this manner, two measurement errors are introduced. On the one hand, some of the people in the city of Santa Cruz must be engaged in agriculture and they were assumed not to be. But on the other hand, not all of the "rural" population outside of the city of Santa Cruz is necessarily agricultural since several other medium sized towns exist in the five provinces. Each error operates in the opposite direction from the other and might about offset each other. In any case, no data exists to test the reliability of the assumption employed.

Assuming an average of 20 working days per month, and an employment level of 95 percent, the maximum local labor constraint per period is estimated at 1,997,444 man-days.

Migrant labor

Agricultural labor from other departments has been hired seasonally for sugar harvesting for many years. In the last few years, with the increasing cultivation of cotton, the demand for outside agricultural labor has grown markedly since cotton in Bolivia relies heavily on human labor for harvesting. A rough estimate of the labor requirement for cotton harvesting is one man per hectare during the whole harvesting period.

A limiting factor to cotton production in the future will probably be the limited availability of labor for the harvest. Machine harvesting is technically feasible, but it lowers the quality of the final product and, up to this time, has not been utilized.

No information is available about the supply curve of migrant labor facing the agricultural sector in Santa Cruz. In other words, it is not known how far wages would have to be increased in order to draw larger numbers of migrant workers into the area from the remainder of the country.

If additional agricultural labor is hired from other areas, the higher wages should at least reflect the marginal cost of moving into the area. These per diem and transport costs have been roughly estimated at \$b 40 per person. Assuming an average working period of two months (40 days) for the migrant worker, it means a salary increase of \$b 1.00/day.

Since no information is available on the supply curve of migrant labor, it is assumed that local wages in the other areas are the same as those of the Santa Cruz area. Therefore, at the margin, additional labor could be supplied if the \$b 1.00/day of moving expenses is added to the basic wages. It is estimated arbitrarily that the amount of migrant labor available at this wage would be equal to half of the quantity of local labor supply; that is, 25,000 men. Additional step increases of \$b 1.00/day are also arbitrarily assumed for the labor supply function for each additional increment of 25,000 men, or one million man-days (see Figure 9).

The next step is to estimate a marginal factor cost curve, since each increase in labor hired would mean higher wages not only for the additional labor, but for all those already working as well.

Each point on the MFC curve can be calculated using the equation:

$$MFC = P(1 + \frac{1}{\varepsilon}) = P(1 + \frac{1}{2}) = 1.5P$$

where

P = wage level on the supply function

ε = supply elasticity

No information is available on the elasticity of supply, but since Bolivia is a country where about 80 percent of the population is engaged in subsistence farming, and where the traditional agricultural areas are

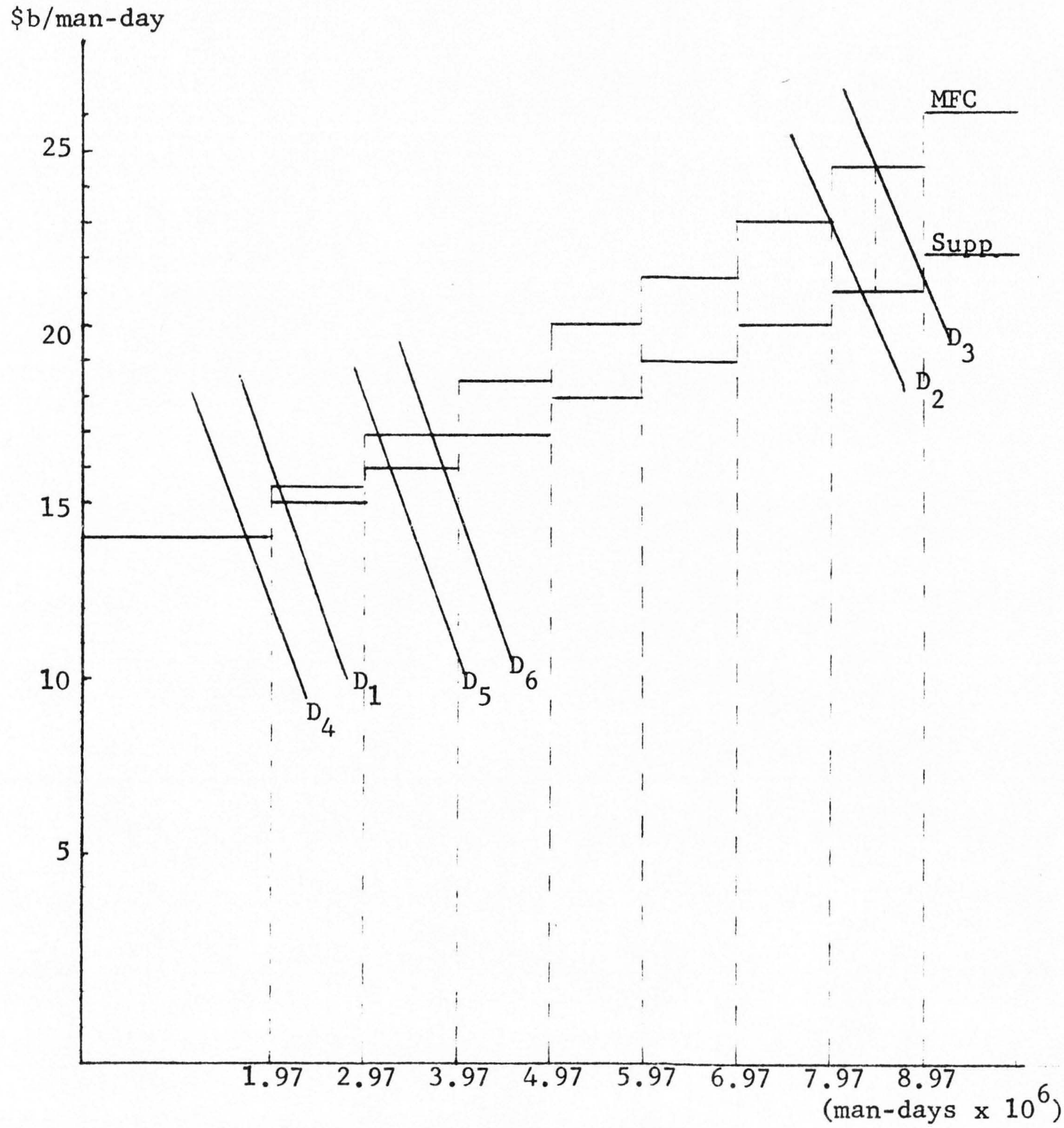

Figure 9. Estimated supply function of labor and its intersections with demand at each time period.[a]

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[a]The vertical axes fit the crops where the local labor wages are equal to $b 14.0/day, otherwise everything should be shifted down by $b 1.15/day to fit the crops with a $b 12.85/day level of local wages.

densely populated (as is the case in the Cochabamba valley and certain portions of the Altiplano) surely there must be a certain amount of under-employment of agricultural labor. Therefore, it seems reasonable to expect that the percent increase in labor supplied would be larger than the percent increase in wages. In other words, the elasticity of supply should be larger than unity.

The total interval of the positively sloped labor supply curve being considered does not go above 250,000 persons at the highest assumed wage levels. The total labor force in the country has been estimated at 1,198,600 persons in 1967.[22] The rate of growth of the rural population was also estimated at 2.28 percent a year. Therefore, the size of the labor force should be about 1,282,000 in 1970.

To draw an amount of migrant labor below 20 percent of the total agricultural labor force into Santa Cruz for cotton and sugar cane harvesting should not require running into the relatively more inelastic portions along the labor supply function. Another fact that one should have in mind here is that women are also hired to work in cotton harvesting. Therefore, the required amoung of labor would even be a smaller proportion of the total available.

In view of these considerations, assuming an elasticity of supply of labor of 2.0 appears to be reasonable.

The MFC curve, therefore, increases in steps of $b 1.50 each rather than $b 1.0 as is the case for the supply function (see Figure 9).

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[22] Ministerio de Planificación y Coordinación, República de Bolivia, "Estrategia Socio-Económica del Desarrollo Nacional, 1971-1991," 1970, p. 567.

Since the amount of labor required for the cotton and sugar cane harvest is critical in view of the limited supply, special care has been taken in handling the time distributions of each operation.

Cotton harvesting is an operation that cannot be delayed since a sudden rain can both lower the yield and require additional efforts to dry it. Therefore, it has been assumed that cotton harvesting should be evenly distributed during the entire season. The alternative would be to let the model spread cotton harvesting over time in the least cost fashion, which would be during the time periods where equilibrium in the labor market is at lower wages, but this would clearly be wrong.

Even though sugar cane gross yields and sugar content are reduced if harvesting is not done at the proper time, this is not a factor so sensitive as in the case of cotton. Accordingly, no fixed constraint has been placed on sugar cane harvesting except for the obvious fact that it should be done before the beginning of the rainy season since transportation then on secondary roads becomes practically impossible.

Sugar cane harvesting can be spread over the entire dry season, from May to October, roughly six months. In order to introduce more flexibility into the program, therefore, no constraint has been set on the proportion of the total that should be harvested within each time period. The production constraints due to the limited milling capacity have been applied separately to each time period.[23]

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[23] The next section shows the production constraints used. Storage before milling is not feasible since the quality and sugar content deteriorate very rapidly.

Labor Equations

The labor input equations follow the general format indicated for otherinputs. The difference in treatment appears when entering these factors into the objective function. Since no constant labor wage rate exists, the labor marginal factor cost curve has been estimated.

The total amount of labor required per time period when all the crops are added is calculated:

$$\sum_j L_{ij} - L_j = 0$$

where: L_{ij} : total labor requirement for the i^{th} crop during the j^{th} time period.

L_j : total labor requirement in the j^{th} time period.

A maximum constraint equal to the maximum availability of local labor was then placed on labor for each period, but at the same time additional variables were introduced representing each one of the steps on an assumed labor supply curve:

$$L_j - \sum_i M_{ij} \leq K_L$$

where: M_{ij} : i^{th} migrant labor required in the j^{th} time period.

K_L : availability of local labor (it does not vary from one time period to the other).

As mentioned earlier, the basic wages paid when no migrant workers are required have been estimated to be $b 14.00 per man-day for some crops and $b 12.85 per man-day for the others. Therefore, rather than entering the total amount of labor required by all crops and time periods as a single term in the objective function, a different entry was allowed for each separate crop. The result is that the total amount of labor used is being charged a cost equal to the basic wages. Since a step function has been assumed for labor supply, all of the labor above the local labor availability should be charged, not only the local labor wages estimated but an additional amount in order to reach the marginal factor cost value. It was necessary to differentiate the migrant labor requirement corresponding to each one of the step increases on the MFC curve. For this purpose a maximum constraint was established for each step on the migrant labor requirement for each time period:

$$M_{ij} \leq M_L$$

where: M_{ij} : i^{th} migrant labor required in the j^{th} period.

M_L : maximum estimated availability of the ith migrant labor required (it does not vary for the different time periods, and was estimated to be of 25,000 men or 10^6 man-days as mentioned earlier).

The quantity of the i^{th} migrant labor required by all the crops combined, irrespective of the time periods was calculated as:

$$-M_i + \sum_j M_{ij} = 0$$

where: M_i : total requirement of the i^{th} migrant labor.

The first step increment on the MFC curve is equal to \$b 1.5 per man-day over and above the basic wage paid, and the additional step increments are also \$b 1.5 per man-day above the preceding one. Therefore, since all labor had already entered the objective function at the basic wage level, it was necessary to enter the migrant labor requirements with only the cost margin above the basic wage:

$$1.5\ M_1 + 3.0\ M_2 + 4.5\ M_3 + 6.0\ M_4 \ldots\ldots$$

Production Constraints

Sugar cane

The daily milling capacity in existence is:

Milling plant	Mt/day
Guabirá	2,800
La Bélgica	3,500
San Aurelio	3,400
Total	9,700

The total capacity for each two month period is, therefore, equal to 60 x 9,700 = 528,000 metric tons. These constraints have been introduced into the linear program as production constraints 11, 14, and 15 for the periods 3, 4, and 5 (May to October), respectively. If any critical constraints are found, particularly labor for the harvest, this feature will make it possible for the program to reduce sugar cane harvesting in the time period where it is relevant, without reducing the production capacity in the other time periods.

Soybeans

Soybeans are the newest commercial crop in the area. Its production is centered around the San Juan colony, and it has a potential role to play in solving the large table oil deficit in Bolivia. If production continues to increase, soybeans might even become an export crop. But since this possibility was not even being explored at the time of the production survey (June, 1972) in view of the sizeable domestic deficit in table oil production, no provisions have been made in the program for export possibilities.

Assuming that the proposed oil processing plant is built by the Corporación Boliviana de Fomento (CBF) with a production capacity of 10,000 metric tons of oil per year, and that there is a market demand for those 10,000 metric tons of oil, if 80 percent of the oil is made with soybeans, then 8,000 metric tons of oil will be made of soybeans. With a 33 percent oil yield, 24,000 metric tons of soybeans would be required, or 528,000 cwt. This has been put in the program as production constraint 12.

Yuca

This crop is produced in small plots mostly in the vicinity of the farm house. A negligible proportion of the total production goes to starch production (there is a processing plant in Cochabamba). The proportion that goes to the market is also very small since for all practical purposes the market is limited to the city of Santa Cruz because practically all the farms have their own yuca plots. The common practice is to harvest it continuously throughout the year to satisfy daily home consumption. It can be safely assumed that the demand for yuca is realtively inelastic. Being a basic food item that occupies an important position in the rural diet in the area and its relatively costly to transport, its demand is not likely to be very sensitive to price fluctuations.

It has been arbitrarily assumed that present production levels will not increase or decrease by more than 30 percent. This constraint shows up as a land constraint, since no yield changes are foreseen. Table 29 illustrates the maximum and minimum constraints set on land for yuca production in each province.

Table 29. Constraints on land for yuca production, in hectares

	Province					
	Santisteban	Sara	Warnes	Ibáñez	Ichilo	Total
Present use (1971-72)	650	1,400	1,200	719	2,500	6,469
Maximum	845	1,820	1,560	935	3,250	8,410
Minimum	455	980	840	503	1,750	4,528

Rice

The agricultural bank manages a price support policy for rice production. Every year it establishes a minimum fixed price at which it is obligated to buy all the rice offered.

Of a total production of about 1,580,000 cwt in 1971 purchased by the Bank, only 674,896 cwt were marketed by the Bank, leaving a surplus stock of around 44 percent of the total production, mostly lower grade rice.[24] Since no serious attempt was made to open any export markets, mainly because of the relatively high prices in relation with world market prices at the time of the survey, no export possibilities have been assumed, although this constraint could be relaxed.

A maximum constraint has been placed on rice production based on future consumption estimates. The assumed linit is the estimated value of total national consumption for 1972, at 49,215 metric tons of milled rice.[25] This estimate may be biased upward on two counts: first, it is for the year 1975 rather than 1972 as are the rest of the estimates;

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[24] Utah State University/Usaid/Bolivia, Irrigation Analysis for Selected Crops: Santa Cruz, Bolivia, USU Series 13/72, July 1972, p. 119.

[25] Preliminary estimates of the long term demand for agricultural products in Bolivia. Allen LeBaron, et al, Cususwash/Ut/Econ. P5/AID/csd 2167, April 1971, Table 6.

and second, because it ignores the fact that only about 82 percent of Bolivia's rice is produced in Santa Cruz. But in spite of these limitations, the estimate seemed the best available for use as a maximum production constraint. It has been introduced as production constraint 13, at 49,215 metric tons or, 1,032,730 cwt.

CHAPTER III

OPTIMUM LAND ALLOCATION UNDER PRE-DEVALUATION PRICES AND WAGES

In order to interpret correctly the results obtained from the linear program, two features of the analysis must be kept in mind: first, the assumptions relating to the supply of migrant labor, which have been discussed in Chapter II and whose final results are illustrated in Figure 9, and second, the introduction of newly cleared land for summer production of cotton, with soybeans and wheat as winter crops. The additional inputs required for land clearing have not been included as a lump sum in the first-year costs, but rather have been amortized over time by taking 15 percent of their value as annual costs. The results, therefore, should not be interpreted to mean that the programs land allocation is an immediate optimal allocation for 1971-72, but that economic forces should push land allocation in the direction of this optimum as farmers attempt to maximize net incomes. In addition, "the optimum solutions" obtained will be defined by the assumptions introduced into the model. Therefore, they will not necessarily provide with a "true optimum" if the real world conditions depart from the assumptions of the model.

Land Constraints

Land presently in use

Let us first compare the results obtained from the program for the portion of the land presently under cultivation (Table 30) with the

Table 30. Optimum land allocation under pre-devaluation prices, in hectares

Land presently in use	Provinces					
	Santisteban	Sara	Warnes	Ibañez	Ichilo	Total
Summer mechanized soybeans	---	730	---	9,095	1,630	11,455
Hand soybeans	---	---	4,856	---	---	4,856
Winter mechanized soybeans	---	---	---	---	---	---
Total soybeans	---	730	4,856	9,095	1,630	16,311
Winter wheat	5,945	3,006	5,168	9,095	1,630	24,844
Cotton	19,817	4,342	17,226	---	---	41,385
Corn	---	---	---	---	---	---
Mechanized rice	---	---	---	---	---	---
Hand rice	1,221	13,196	---	---	12,292	26,709
Yuca	845	1,820	1,560	503	3,250	7,978
Sugar cane	31,848	---	---	13,976	---	45,824
Total	59,676	23,094	28,810	32,669	18,802	163,051
New clearing land						
Winter mechanized soybeans	---	---	---	---	---	---
Winter wheat	9,692	6,692	22,405	56,852	---	95,641
Cotton	32,306	22,308	74,684	106,456	5,181	240,935
Grand Total	101,674	52,094	125,899	195,977	23,983	499,627

estimates of actual land use in 1971-72 (Table 20). The first thing that can be observed is that the totals in Table 30 are slightly higher, even though land constraints 1 to 20 set the totals of Table 20 as maximum constraints. The estimate of total land presently under cultivation is 155,452 hectares (Table 20), and the model predicts the cultivation of 163,051 hectares not requiring to be cleared. The reason lies in the introduction of land use coefficients (Table 27) which make it possible to bring new hectarage into cultivation by double cropping.

All of the land presently cultivated is used in the program (land constraints 1 to 20) with the exception of Warnes province where 9,174 hectares are left unused, and Ichilo province where 8,872 hectares are not used.

The reasons why the program left part of the land unused in Warnes and Ichilo provinces are: first, all of the land available for mechanized cultivation in those two provinces has been allocated by the model; second, with regards to the hand cultivated crops, sugar cane, soybeans, and rice have all reached maximum production constraints, yuca has been assigned the maximum amount of land set in the model for the two provinces, and finally corn is not being produced at all in the optimum allocation given by the model. It can still be argued why out of all the land assigned to hand cultivation of rice and sugar cane did the model select the other provinces leaving portions of unused land in Warnes and Ichilo. The reasons are: first, the yield of hand-cultivated rice is lower in these provinces (34.54 and 40.26 cwt/hectare, as compared to average expected yields for Santisteban and Sara of 41.58 and 40.70 cwt/hectare), and second, they are not as efficient in sugar cane production as are the provinces of Santisteban and Ibáñez because of their lower expected yields and higher transport costs to the mill (see Table 18, and Table 88, Appendix C).

The land constraints on cotton for land presently in use are not reached in any of the provinces (land constraints 21 to 25). Cotton production has been assigned the entire amount of land available for mechanized cultivation in the provinces Santisteban and Warnes. In the provinces Ibáñez and Ichilo cotton was assigned land to be cleared until the constraint on maximum total cotton land was reached.

The portion of unused land available for mechanized production was then allocated to the next best alternative to cotton: soybeans, until all the available land for mechanized production was used.

In the remaining province Sara, the total available land for mechanized production (5,072 hectares, Table 23) has been shared by both cotton and summer mechanized soybeans with 4,342 and 730 hectares respectively (see Table 30).

The shadow prices of land, that is, the net increase in the annual income if one additional hectare is available are shown in Table 31. The price of one hectare of hand cleared land has been estimated at \$b 815.00 (Table 84, Appendix A), and \$b 2,504.54 for mechanically cleared land.[26] Assuming a 15 percent annual rate of discount, the present values of a continuous flow of income equal to the shadow prices of land have been calculated in Tables 31 and 32.

The shadow prices of Table 31 can be used to reflect the economic incentive to increase the amount of hand cultivated land. Since the present value of the shadow prices is below the estimated actual price of hand cleared land, no incentive seems to exist to increase the hectarage of hand cleared land. In the case of the land growing crops that require mechanized technology, however, the results show the opposite; all the present values (Table 32) are higher than the price of land mechanically cleared reported in the survey. Thus, there are economic incentives for clearing additional land (or cleaning of tree stumps and levelling the land previously farmed by hand) by mechanical means.

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[26] In the production survey, farmers were asked to quote price estimates for their land or a similar one in the vicinity. The average values were calculated.

Table 31. Shadow prices of land for hand cultivation, in $b per hectare

Province	Shadow price	Present value[1]
Santisteban	19.14	127.60
Sara	6.38	42.53
Ibáñez	103.64	690.93

[1]A 15 percent annual rate of discount over an indefinite period of time is assumed

Table 32. Shadow prices of land for mechanized production, in $b per hectare

Province	Shadow price	Present value[1]
Santisteban	557.61	3,717.40
Sara	415.00	2,766.67
Warnes	576.74	3,844.94
Ibáñez	437.93	2,919.53
Ichilo	437.93	2,919.53

[1]A 15 percent annual rate of discount over an indefinite period of time is assumed

As stated earlier, all of the available land for mechanized production has been allocated by the program. This is precisely the reason why the assumption was made to permit further mechanical land clearing.

With regards to double cropping it should be observed that the program allows only 0.86 hectares of winter wheat for each hectare of cotton. If the coefficients estimated for the time distribution of the land use for each crop (Table 27) are to be used, only 3 hectares of wheat could be planted for each 10 hectares of cotton because of the constraints on the first two months of the year. Since such a constraint appeared to be excessively high, it has been taken out of the model. As an alternative, the next tightest constraint has been used: in March and April, 69 percent of the cotton land is not in use while 80 percent of the wheat land is already under cultivation; therefore, only 86 percent (.80/.69 = .86) of the cotton land could be double cropped.[27]

Table 30 shows that of a total predicted 24,944 hectares of wheat land presently in use, 9,095 hectares in Ibáñez and 1,630 hectares in Ichilo are double cropped with soybeans (43 percent of the total wheat produced). Wheat is double cropped with cotton in Santisteban and Warnes while up to 730 hectares out of 3,006 in Sara could be double cropped with soybeans. If this is the case, 11,455 hectares would be double cropped with soybeans (46 percent) and 13,389 hectares would be double cropped with cotton (54 percent). This is an indication that if mechanized production of soybeans is implemented on a scale larger than that stipulated by the maximum constraints imposed on soybeans production

[27]This is included in the model as land constraints 71 to 75.

in the model, winter wheat production double cropped with soybeans would probably become effective.

New land to be cleared

Only in the provinces of Santisteban, Sara, and Warnes does all of the new land estimated to be available (Table 25) get allocated in the model, while 62,745 hectares in Ibáñez, and 123,643 hectares in Ichilo remain unused. The reason why the model does not assign more newly cleared land to cotton production in Ibáñez and Ichilo is that the constraints on total land (land already in cultivation as well as newly cleared land) available for cotton production have been reached in Ibáñez, Ichilo, and Sara (see Tables 26 and 34).

Table 35 contains the shadow prices for constrained cotton classified according to the type of limiting constraint applicable. For all provinces, net income gains resulting from each additional hectare of cotton production are above $b 557.61.

These shadow prices are large enough to indicate that a significant amount of incentive would exist for increasing the amount of land available for cotton production and even the clearing of more land than the maximum potential estimates assumed in the model. There is no doubt that additional tracts of land could be brought into cotton production, but this would mean entering into areas with climate and soil conditions less suitable for cotton production and with added difficulties in obtaining adequate access roads.

Production Constraints

All of the maximum production constraints have been reached with the exception of land in yuca in Ibáñez, where hectarage went down to the minimum production constraint (the shadow prices are contained in Table 36). The negative value of the shadow price for yuca land in

Table 33. Land presently in use allocated to mechanized crops, in hectares

Crop	Province: Santisteban	Sara	Warnes	Ibañez	Ichilo	Total
Summer soybeans	---	730	---	9,095	1,630	11,455
Winter soybeans	---	---	---	---	---	---
Winter wheat	5,945	3,006	5,168	9,095	1,630	24,844
Cotton	19,817	4,342	17,226	---	---	41,385
Rice	---	---	---	---	---	---
Total	25,672	8,078	22,394	18,190	3,260	77,684

Table 34. Total land allocated to cotton, in hectares

	Province: Santisteban	Sara	Warnes	Ibañez	Ichilo	Total
Land presently in use	19,817	4,342	17,226	---	---	41,385
Newly cleared land	32,306	22,308	74,684	106,456	5,181	240,935
Total	52,123	26,650	91,910	106,456	5,181	282,320

Table 35. Shadow prices for cotton in land presently in use and newly cleared land, in $b per hectare

Nature of the constraint	Province: Santisteban	Sara	Warnes	Ibañez	Ichilo
Land presently in use	557.61	---	576.74	---	---
Newly cleared land	563.31	---	563.31	---	---
Total cotton land	---	563.31	---	563.31	563.31

Table 36. Shadow prices resulting from the production constraints on land

Crop	Unit	Shadow price
Yuca in Santisteban	$b per hectare	68.47
Yuca in Sara	$b per hectare	81.22
Yuca in Warnes	$b per hectare	87.60
Yuca in Ibáñez	$b per hectare	-16.03
Yuca in Ichilo	$b per hectare	87.60
Sugar cane in May and June	$b/metric ton	0.67
Sugar cane in July and August	$b/metric ton	12.01
Sugar cane in September and October	$b/metric ton	8.77
Soy beans total	$b/cwt	11.97
Rice total	$b/cwt	9.40
Cotton[a]	$b/cwt	43.84

[a]This is an equivalent shadow price calculated by dividing the shadow price per hectare, by the expected yield: 563.31/12.85 = 43.84 $b per cwt.

Ibáñez means that if the minimum constraint of 503 hectares is increased by one unit, there will be a loss of net income equal to $b 16.03.

Labor Constraints

Since the labor requirements have been broken down according to the time period in which they occur, it is possible to see where the shifting demand curve of labor intersects the assumed supply function at each time period.

The significant difference between the migrant labor requirements for periods 2 and 3 (150,000 and 164,589 persons) as compared with the rest of the year shows clearly the need for itinerant workers that are hired for periods of less than 4 months for the harvesting season every year. In the case of cotton and sugar cane harvesting, where the local wages were estimated at $b 14.0 per man-day, the equilibrium level is at $b 20.0 and $b 21.0 per man-day for periods 2 and 3. Obviously the reliability of these results depends on the validity of the assumptions about the supply curve of labor (see Table 37 and Figure 9).

General Results

As it was mentioned above, all cotton, sugar cane, soybeans, rice, and yuca reached maximum constraints placed either on the available land or the maximum amounts to be produced, with the exception of yuca in Ibáñez province. Of the two remaining crops, corn is not assigned any land at all because it cannot compete with the other crops at the assumed prices. Wheat in cleared land is produced as a winter crop to double crop with summer soybeans in Ibáñez and Ichilo, and with cotton in Santisteban and Sara, and with either cotton or soybeans in Warnes. All wheat in land to be cleared is to be double cropped with cotton, according to the model.

A comparison between the actual pattern of land allocation estimated for 1971-72 and the optimum one described by the model (Tables 20 and 30) shows an increase from 35,501 to 45,824 hectares for sugar cane, yuca is also increased from 6,469 to 7,978 hectares, soybeans shows a large increase from 1,800 to 16,311 hectares. This land allocation to soybeans could have been even higher if a maximum constraint on quantity produced was not introduced.

Cotton is assigned 240,935 hectares of newly clearing land and 41,385 hectares of land presently in use, a dramatic increase over the amount of land presently cultivated (47,580 hectares).

Table 37. Labor input requirements per time period

Period	Local labor man-days	Migrant labor man-days	Total man-days	Added[a] MFC $b/MD	Migrant[b] labor men
January-February	1,977,444	248,983	2,226,427	1.5	6,225
March-April	1,977,444	6,000,000	7,977,444	9.0	150,000
May-June	1,977,444	6,583,567	8,561,011	10.5	164,589
July-August	1,342,962	---	1,342,962	---	---
September-October	1,977,444	1,071,089	3,048,533	3.0	26,777
November-December	1,977,444	1,236,926	3,214,370	3.0	30,923

[a]This is over and above the local labor wages.

[b]Calculated by dividing the migrant labor requirement by the expected length of the harvesting season (2 months or 40 days).

Rice is decreased from 34,592 to 26,709 hectares, all of it in hand cultivation, but this reduction is the result of the maximum constraint placed on the quantity of rice to be produced.

Corn production, as it was mentioned earlier, suffers the most significant reduction by the model, from 29,510 hectares to none.

Parametric Analysis of the Objective Function

Product prices as well as labor wages were allowed to vary one at a time while all other coefficients in the objective function were held constant. The effect of the price changes on the land allocation in each crop has provided us with several points on the estimated potential supply curve of the crop. That is, the program has calculated an optimum point for each given set of prices. The "optimum solutions" obtained are defined by the assumptions introduced into the model. Therefore, they do not necessarily provide with a "true optimum" if the real world conditions depart from the assumptions of the model. By introducing changes in the basic wage paid if no migrant labor is required, the assumed supply function of labor has been allowed to shift parallel wise. Thus, it has been possible to obtain additional points on the demand functions of labor for each time period. It must be observed that all these demand functions are being analyzed at the same time since the same wage changes are introduced simultaneously for the six time periods.

Soybeans supply response

The maximum constraint on total soybeans production was reached at the assumed price of \$b 58.2 per cwt. The important question then is the supply response to lower prices. The price was parametrically decreased by \$b 5.0 per cwt steps. No departure from the maximum occurs until the price is dropped to \$b 43.2 per cwt where summer hand soybeans is reduced to zero hectares while summer mechanized soybeans goes down from 11,455 to 4,245 hectares. Finally, all soybeans production is rejected at the \$b 33.2 per cwt price (Table 39). Both winter mechanized soybeans and mechanized soybeans in newly cleared land are not competitive with the other two methods of production at any of the assumed prices. World market prices for soybeans are actually increasing so that a considerable amount could be exported. Table 40 shows the average prices received by the farmers in the United States in the last decade. At a

Table 38. Equilibrium wages and intersection of the demand and marginal factor cost curves, in $b per man-days[a]

Period	MFC	Equilibrium wages
January-February	15.5	15.0
March-April	23.0	20.0
May-June	24.5	21.0
July-August	14.0	14.0
September-October	17.0	16.0
November-December	17.0	16.0

[a]From Figure 9.

Table 39. Soybeans supply response[a]

Price	Summer mechanized soybeans		Summer hand soybeans		Total soybeans	
$b/cwt	hectares	cwt	hectares	cwt	hectares	cwt
58.2	11,455	400,925	4,856	127,075	16,311	528,000
53.2	11,455	400,925	4,856	127,075	16,311	528,000
48.2	11,455	400,925	4,856	127,075	16,311	528,000
43.2	4,245	148,572	---	---	4,245	148,572
38.2	4,245	148,572	---	---	4,245	148,572
33.2	---	---	---	---	---	---

[a]The model did not record any supply response for winter mechanized soybeans and mechanized soybeans in newly cleared land at any of the assumed prices.

Table 40. Season average prices received by farmers in the United States[a]

	Corn		Rough rice		Cotton lint[b]	
Year	US$/ bushel	US$/ cwt	US$/ bushel	US$/ cwt	US$/ cwt	US$/ cwt
1962	1.12	2.00	2.04	3.40	5.04	31.90
1963	1.11	1.98	1.85	3.08	5.01	32.23
1964	1.17	2.09	1.37	2.28	4.90	29.76
1965	1.16	2.07	1.35	2.25	4.93	28.14
1966	1.24	2.21	1.63	2.72	4.95	20.64
1967	1.03	1.84	1.39	2.32	4.97	25.39
1968	1.08	1.93	1.24	2.07	5.00	22.02
1969	1.15	2.05	1.24	2.07	4.95	20.94
1970	1.33	2.37	1.33	2.22	5.17	21.86
1971[c]	1.42	2.54	1.40	2.33	5.27	21.00
1972[c]	1.09	1.95	1.33	2.22	5.53	29.45
1973[c]	1.39	2.48	2.38	3.97	7.95	22.13
1974[c]	2.59	4.62	5.29	8.82	15.80	57.20

[a]The transformation coefficients used are: 45 lb per bushel for rice; 60 lb per bushel for wheat and soybeans; 56 lb per bushel for corn; and 152 lb of rough rice per 100 lb of milled rice equivalent.

Source: Agricultural Prices, Statistical Reporting Service, U.S. Department of Agriculture, Washington D.C. Annual Summaries 1967 and 1971.

[b]American upland

[c]These prices are the average prices for the month terminating on January 15 of the year indicated.Monthly summaries 1971;72; 73; and 74.

constant exchange rate of $b 12.0 per US dollar the prices would be $b 58.44 per cwt in 1972, increasing to $b 81.96 per cwt in 1973, and $b 117.36 per cwt in 1974. Thus the omission of export possibilities for soybeans appears to be a serious weakness of the model. But one must remember that at the time of the survey soybeans production at a commercial scale was very limited, and, therefore, the data collected through the interviews with the farmers, and from other secondary sources may not be very reliable. But to the extent that they do represent the real situation, the future for soybeans, including export, appears very bright indeed.

Wheat supply response

If wheat prices decrease only slightly from $b 46.750 to $b 46.748 p per cwt, wheat production on newly cleared land would decrease from 1,912,825 to 775,788 cwt with labor 38 entering the basis at its upper limit. (Labor 38 is the constaint that sets a maximum of 7.97×10^6 man-days of labor at $b 23.0 per man-day for marginal factor cost in Figure 9.) As a matter of fact, that is exactly the price at which labor demand in period 2 (March and April) intersects the supply function. In order to increase wheat production additional labor must be hired at the next higher MFC level.

Wheat production on land presently in use is caught between two land constraints. The maximum availability of mechanically cleared land in Ibáñez, and a maximum constraint on total cotton land in Sara. Wheat prices must decrease below $b 45.75 per cwt before any portion of that land in Ibáñez is left unused. They should go above $b 53.22 per cwt in order to compete with cotton production.[28]

The results of the parametric analysis of the objective function confirm what was observed above. If the price is lowered to $b 36.75 per cwt no land is allocated to wheat production, while a significant increase results if the price is increased to $b 56.75 per cwt. At that

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[28]These results were observed applying a RANGE routine on the program. This routine shows how far the coefficients in the objective function can be changed one at a time before a change in the basis results.

Table 41. Wheat supply response

Price	Land presently in use		Newly cleared land		Total	
$b/cwt	hectares	cwt	hectares	cwt	hectares	cwt
86.75	51,157	1,023,147	191,705	3,834,094	242,862	4,857,246
76 75	51,157	1,023,147	191,705	3,834,094	242,862	4,857,246
66.75	51,157	1,023,147	191,705	3,834,094	242,862	4,857,246
56.75	51,157	1,023,147	191,705	3,834,094	242,862	4,857,246
46.75	24,844	496,877	95,641	1,912,825	120,485	2,409,702
36.75	---	---	---	---	---	---

price, total production increases from 2,509,702 to 8,499,945 cwt (Table 41). At higher prices, the supply curve becomes perfectly inelastic and no additional response is forthcoming even if the price goes as high as $b 106.75 per cwt. The reason is that the maximum constraints on land availability have been reached. One important assumption here is that wheat production on land to be cleared is being double cropped with another crop (in the program all land clearing costs have been assigned to cotton), otherwise the supply response probably would be less than that indicated.[29]

[29] Wheat prices in the world market have risen sharply since 1972. Prices received by the farmers in the U.S. have increased from US$ 2.22 per cwt in January 1972 to US$ 3.97 and US$8.82 per cwt in January 1973 and 1974 (Table 40). At a constant exchange rate of $b 12.0 per US$, these prices would be $b 26.6; $b 47.6; and $b 105.8 per cwt. At present they seem to be falling again. In 1971 the transport costs of a metric ton of flour from the coast of the US to La Paz were equal to $b 720.84. (Enrique Gómez, et al., Wheat Study, Ministry of Agriculture, Bolivia,

Cotton supply response

At the estimated current price of $b 350.0 per cwt, the program assigned cotton production in the provinces Sara, Ibáñez, and Ichilo at the maximum amounts of land assumed to be available : 26,650; 106,456; and 5,181 hectares respectively. Any further increase in the price would only create a redistribution of the available land between cotton in land presently in use and cotton in land to be cleared, in the three provinces.

Cotton produced on land presently in use, in the provinces Santisteban and Warnes was allocated the maximum availability of land mechanically cleared (19,817 and 17,226 hectares respectively). Cotton on land to be cleared in the two provinces, was limited by the maximum constraints on that class of land. Therefore, no change in land allocation could result from further increases in cotton prices.

Table 42 shows the supply response of cotton to reduced prices. At a price of $b 230.0 per cwt cotton production is no longer profitable in any of the provinces; that is, if cotton prices received by the producers are reduced by 34 percent from $b 350.0 to $b 230.0 per cwt because of a drop in world market prices or the establishment of government duties on cotton sales or exports, then cotton production could be completely wiped out unless, of course, some of the price assumptions are no longer valid at lower levels of cotton production. The domestic

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1972, Table 4). Ignoring the transportation and handling costs of wheat within the U.S., a minimum additional cost of $b 32.8 per cwt (assuming no increase in transport costs) or $b 720.84 per metric ton should be added to estimate approximately the cost of importing wheat from the U.S. The prices quoted above would then increase to $b 59.4; $b 80.4; and $b 138.6 per cwt.

Table 42. Cotton supply response

Price	Presently in use		Newly cleared land		Total	
$b/cwt	hectares	cwt	hectares	cwt	hectares	cwt
350.0	41,385	531,797	240,935	3,096,015	282,320	3,627,812
330.0	41,385	531,797	240,935	3,096,015	282,320	3,627,812
310.0	30,688	394,340	233,725	3,003,365	264,413	3,397,705
290.0	36,301	466,462	62,033	797,134	98,334	1,263,596
270.0	26,540	341,040	---	---	26,540	341,040
250.0	1,219	15,668	---	---	1,219	15,668
230.0	---	---	---	----	---	---

demand curve for cotton could intersect the supply curve at a price above $b 230.0 per cwt, and/or the lower wages that result from a reduction in the total demand of agricultural labor in the entire area could still make cotton competitive with the other crops at lower levels of land allocation.[30]

The average prices received by farmers in the U.S. for cotton lint, American Upland variety, have not been below US$ 20.64 per cwt in the last twelve years (see Table 40). The transport cost of cotton from Santa Cruz to a seaport on the South American coast (either Buenos Aires or Santos) has been estimated by the Cotton Producers Association

[30]The effect of taxes on cotton is studied in more detail in Chapter V.

at US$ 2.5 per cwt.[31] If the additional transport costs to the U.S. are roughly estimated at US$ 2.0 per cwt, the total figure would be US$ 4.5 per cwt. Equating the price received by the U.S. farmers with that of Bolivian cotton delivered to the U.S. coast, the actual price of cotton in Santa Cruz would be approximately US$ 16.14 per cwt if the U.S. price is US$ 20.64 per cwt. The price received by the Bolivian farmers would be $b 193.7 per cwt if a constant exchange rate of $b 12.0 per US$ is assumed.

If the recent 67 percent devaluation of the Bolivian peso in relation to the U.S. dollar had not occurred, such a swing in cotton prices could have made Bolivian cotton unprofitable for the export market. To estimate an equivalent cost of importing U.S. cotton to Santa Cruz, the margin of US$ 4.5 per cwt of transport costs would be added to the price received by U.S. farmers.[32] The price of cotton in Santa Cruz would be 20.64 + 4.5 = 25.14 US$ per cwt, i.e., $b 301.7 per cwt (at $b 12.0 per US$). Therefore, it would still be profitable to produce cotton for the domestic market since, at this price, the estimated supply curve (Table 42) is intersected at a quantity between 1.26 and 3.40 millions cwt. Total domestic demand at current prices has been estimated at 100,000 cwt.[33]

Corn supply response

At the assumed predevaluation price of $b 21.18 per cwt, corn production is not competitive in any of the provinces, but if the price

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[31] W. Augusto Parra, "El Cultivo del Algodón en el Area de Santa Cruz y sus Necesidades de Capital para el Periodo 1972-73," p. 11.

[32] Costs of transportation between the farm and the sea cost of the U.S. are ignored.

[33] W. Augusto Parra, "El Cultivo del Algodón en el Area de Santa Cruz y sus Necesidades de Capital para el Periodo 1972/73," p. 4.

were increased to $b 22.43 per cwt, corn would become competitive in Ichilo province where the yield was estimated to be the highest (Table 18). Production would be 443,086 cwt on 8,872 hectares (Table 43).

In the last few years, corn production has dramatically diminished. This indicates that the price of corn expected by farmers was around $b 21.18 per cwt or even lower. Corn prices actually fluctuate widely, and the effect of this uncertainty is probably to decrease corn output.

The prices obtained by the San Juan colony in the city of Santa Cruz are an evidence of how much corn prices have deteriorated (see Table 4). The actual history of corn production, therefore, is in agreement with the model: corn is competitive and some corn was produced if prices were in the low 20's but it was not competitive for price levels below $b 20.0 per cwt, experienced in 1970 and 1971.

Table 43. Corn supply response

Price $b per cwt	Hectares	cwt
101.18	150,924	7,005,405
51.18	150,924	7,005,405
41.18	117,610	5,444,136
31.18	61,393	2,979,821
22.43	8,872	443,086
21.18	---	---

Rice supply response

In the last few years milled rice prices have varied slightly (see Table 3). Rice prices in the model apply to the milled product, but since production costs were tabulated for rough rice, an equivalent price for rough rice has been calculated by using an estimated ratio of 70 pounds of milled rice for 100 pounds of rough rice (it is 65.8 pounds in the U.S.), used in the statistical publications of the Ministry of Agriculture in Bolivia. The rough rice equivalent prices would be:

Table 44. Rough rice equivalent prices in Santa Cruz

	Type	
Year	Popular $b/cwt	Extra $b/cwt
1967	42.0	63.0
1968	39.2	63.0
1969	42.0	60.9
1970	39.9	57.4
1971	49.0	58.8

At the predevaluation price of $b 48.23 per cwt for rough rice ($b 68.90 per cwt for milled rice) all rice production is allocated to hand cultivated land until the maximum constraint on total rice production is reached. This describes quite accurately the actual rice situation existing in Santa Cruz in 1971-72 at the time of the survey. Of an estimated production of 1,580,000 cwt in 1971, only about 650,000 cwt reached consumers,[34] showing clearly that at the established price level the supply exceeded the demand. Furthermore, most of the large mechanized commercial farms were turning away from rice production while new producing areas were growing rice on small land parcels farther from the roads and markets and in areas of new colonization.

If the price were to drop to $b 43.23 per cwt, production would remain at the maximum constraint magnitude, but at a lower price of $b 38.23 per cwt the model would decrease rice production from the maximum constraint of 1,082,730 cwt to only 143,935 cwt. At a price of $b 33.23 per cwt rice production cannot compete with any other crop and the supply falls to zero (see Table 45).

Mechanized production of rice is more costly than by manual methods. Therefore, the program allocates all rice production to hand cleared land. It will be observed later that if labor were to become more and more scarce and wages were to rise, mechanized production techniques would be more competitive.

There is a trend towards increased prices in rice, world wide, as evidenced by the increase in prices paid to farmers in the U.S. (Table 40). Rice prices in the U.S. have tripled in the last two years from US$ 5.53 per cwt in January 1972 to 1580 in January 1974. If these high prices were to be obtained in the future, there would be potential for rice exports from Bolivia.

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[34]The remainder was stored by the Agricultural Bank who is in charge of purchasing all the rice production offered at a minimum guaranteed price set in advance every year.

Table 45. Rice supply response

Price	Mechanized Rice		Hand Rice		Total	
$b/cwt	hectares	cwt	hectares	cwt	hectares	cwt
48.23	---	---	26,709	1,082,730	26,709	1,082,730
43.23	---	---	26,709	1,082,730	26,709	1,082,730
38.23	---	---	3,517	143,935	3,517	143,935
33.23	---	---	---	---	---	---

Yuca supply response

The sensitivity analysis shows that yuca prices could vary between $b 8.794 and 9.030 per cwt without causing any change in the quantity produced.[35]

If the price drops below $b 8.794 per cwt, then yuca production in Santisteban would drop from the maximum level of 845.0 hectares to 455.0 hectares, thus lowering total yuca production to 2,726,596 cwt. If the price goes above $b 9.03 per cwt, then yuca production in Ibáñez would go from the minimum to the maximum level (see Table 29).

Sugar cane supply response

A price reduction in sugar cane from $b 70.65 to 69.98 per metric ton[36] would reduce total production to 1,485,543 metric tons by reducing

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[35]The assumptions behind the assumed price for yuca are in Table 16.

[36]Sugar cane prices were fixed at $b 66.0 per metric ton until 1971; the higher price estimate of $b 70.65 per metric ton is probably caused by the expectancy of a higher price, or high saccharine per cents in the surveyed farms. The price was raised to $b 92.0 per metric ton shortly after the survey, in 1972.

the quantity harvested in period 3 (May and June, Table 46) while leaving the other two harvesting periods at their maximum level. At $b 65.65 per metric ton, production drops to 1,164,000 metric tons, and at $b 55.65 per metric ton it is down to 426,636 metric tons, all of which are to be harvested in period 4 (July and August). At a price of $b 50.65 per metric ton no land is allocated to sugar cane production (see Table 46).

If milling capacity for sugar cane were increased, it would be possible to relax the maximum production constraints, particularly the one in period 4 (July and August). Table 36 shows that at the margin, a net gain in total net returns to the agricultural producers of $b 12.01 would be captured for each additional metric ton of sugar cane harvested in July and August; $b 8.77 per metric ton in September and October; and $b 0.67 per metric ton in November and December.

Assuming that these shadow prices hold not only at the margin, but for an additional production of 100,000 metric tons, the total net increase in yearly income for the agricultural producers would be 100,000 (12.01 + 8.77 + 0.67) = 2,145,000 $b. The present value of this stream of benefits, discounted at 15 percent would be 14,300,000 $b. This sum could be compared with the fixed investment necessary to build a new plant or enlarge an existing one by 100,000 metric tons of capacity for each two-month period. If the investment required is below 14.3 millions of $b then it would be economically feasible to build it. If prices paid to sugar cane producers were reduced by 12.01, 8.77, and 0.67 $b per metric ton respectively in each period, the program would not make any changes in the supply function of sugar cane. Moreover, the additional income generated for the millers (assuming that all other things remain constant) would be applied not only to the additional milling

Table 46. Sugar cane supply response

Price $b/MT	Harvested in May & June MT	Harvested in July & August MT	Harvested in September & October, MT	Total Hectares	Total MT
70.65	582,000	582,000	582,000	45,824	1,746,000
69.98	321,543	582,000	582,000	---[a]	1,485,543
65.65	---	582,000	582,000	31,528	1,164,000
60.65	---	582,000	582,000	31,528	1,164,000
55.65	---	426,636	---	13,544	426,636
50.65	---	---	---	---	---

[a]This row was obtained from the RANGE analysis and gave no readily available figure for the hectares cultivated.

capacity but to the entire production. Therefore, in order to recover the investment, the prices paid to sugar cane producers would not necessarily have to be reduced so much.

Effect of Wage Increases Upon Land Allocation[37]

Soybeans

Throughout the entire spectrum of wages that has been analyzed ($b 8.0 to 24.0 per man-day basic wage in all crops with current wages at $b 14.0 per man-day) soybean production remained at its maximum level. The only changes observed were merely shifts of land from one type of soybeans cultivation to another. In land to be cleared, winter soybeans did not receive any land allocation at any wage level. This shows that soybeans production is relatively less labor intensive than

[37]A summary of the results is contained in Tables 47 and 48.

Table 47. Quantity of labor demand and its intersection with the marginal factor cost, for each time period

Time period		Basic wages, in \$b/MD								
		24.0	22.0	20.0	18.0	16.0	14.0	12.0	10.0	8.0
1	MFC \$b/MD	24.0	22.0	20.0	18.0	16.0	15.5	15.5	11.5	9.5
	man-days	1,069,808	1,162,223	1,252,902	1,636,445	1,636,445	2,226,427	2,651,835	2,651,835	2,651,835
2	MFC \$b/MD	31.5	27.0	27.5	27.0	25.0	23.0	22.5	20.5	18.5
	man-days	5,995,072	6,086,676	6,170,648	7,218,671	7,218,671	7,977,444	8,305,537	8,305,537	8,305,537
3	MFC \$b/MD	31.5	29.5	27.5	27.0	25.0	24.5	22.5	20.5	18.5
	man-days	6,856,731	6,910,159	6,967,181	7,555,054	7,555,054	8,561,011	8,696,692	8,696,692	8,696,692
4	MFC \$b/MD	24.0	22.0	20.0	18.0	16.0	14.0	12.0	10.0	8.0
	man-days	333,486	499,713	1,126,780	1,174,941	1,174,941	1,342,962	1,426,661	1,426,661	1,426,661
5	MFC \$b/MD	24.0	22.0	21.5	19.5	17.5	17.0	15.0	13.0	11.0
	man-days	1,445,653	1,977,444	2,420,019	2,759,713	2,759,713	3,048,533	3,297,726	3,297,726	3,297,726
6	MFC \$b/MD	25.5	23.5	21.5	21.0	19.0	17.0	15.0	13.0	11.0
	man-days	2,275,136	2,421,048	2,602,191	3,017,291	3,017,291	3,214,370	3,327,021	3,327,021	3,327,021

Table 48. Land allocation under different basic wages, in hectares

Land presently in use	Basic wages, in $b/MD								
	24.0	22.0	20.0	18.0	16.0	14.0	12.0	10.0	8.0
Summer mechanized soybeans	811	4,245	11,455	11,455	11,455	11,455	4,245	4,245	3,515
Summer hand soybeans	---	---	---	---	---	4,856	14,499	14,499	15,475
Winter mechanized soybeans	19,033	14,454	4,841	4,841	4,841	---	---	---	---
Winter wheat	---	11,561	21,535	20,003	20,003	24,844	24,483	24,483	25,213
Cotton	32,384	28,950	21,740	41,385	41,385	41,385	48,595	48,595	48,595
Corn	---	---	---	---	---	---	8,061	8,061	8,061
Mechanized rice	20,253	20,253	20,253	---	---	---	---	---	---
Hand rice	---	---	---	26,251	26,251	26,709	26,720	26,720	26,712
Yuca	4,528	4,528	4,528	4,528	4,528	7,978	8,410	8,410	8,410
Sugar cane	---	13,976	31,629	31,629	31,629	45,824	45,724	45,724	45,724
Newly cleared land									
Winter soybeans	---	---	---	---	---	---	---	---	---
Winter wheat	---	---	---	---	---	95,641	128,858	128,858	128,858
Cotton	230,291	233,725	240,935	240,935	240,935	240,935	233,725	233,725	233,725

other crops or makes use of labor at time periods when total labor demand is short. Hand soybeans production is obviously the more labor intensive method of soybeans cultivation and is able to successfully compete with winter mechanized soybeans in newly cleared land only at local wages below \$b 16.0 per man-day. In the two remaining methods: mechanized production in winter or summer, the same total amount of labor per hectare and per unit of production is used. But since the winter yield (26.25 cwt per hectare) is estimated to be 25 percent below the summer one (35.0 cwt per hectare), mechanized winter production is more labor intensive than summer production in terms of labor required per each cwt produced. Despite this, as wages increased more and more soybeans production is shifted by the model from the less labor intensive (summer) to the more labor intensive (winter). The reason for this anomaly lies in the different time distribution of the labor requirement. Winter production becomes more efficient at higher wage levels because it makes more use of labor during the time periods of lower total labor demand.

Cotton

Cotton production response to changing wages is quite inelastic on newly cleared land. It fluctuates between 230,291 and 240,935 hectares for all the observed range in local wages from \$b 8.0 to 24.0 per man-day. On the other hand, cotton production on land presently in use is relatively elastic as a function of wage rates, varying between 21,740 hectares at \$b 20.0 per man-day, and 48.595 hectares at \$b 8.0 per man-day.

These results indicate that contrary to what most cotton growers argue, cotton production would not be diminished if wages are actually above the assumed level, since cotton will compete very effectively with the other crops if the general level of wages is raised. The total hectarage would be reduced only from 282,320 hectares at $b 8.0 per man-day to 262,675 hectares at $b 24.0 per man-day. Therefore, higher wages would not seem to force the introduction of labor saving techniques such as mechanical harvesters, although at the margin they are a better alternative at higher than at lower wages.

One word of caution is in order. The above conclusions rely on the validity of the assumptions about the slope of the supply function of labor. If it becomes necessary to increase wages above the assumed levels in order to attract migrant laborers into the Santa Cruz area, wages in peak demand periods (time periods 2 and 3) would tend to be even higher relatively to those in the remaining periods. Since cotton production draws a large proportion of labor during the peak demand periods, it would become more vulnerable to such wage increases. The opposite would also hold; that is, cotton production would become even more profitable if the labor supply function were more elastic to wages than assumed in the model.

Corn

Corn production becomes competitive only at lower wage rates (below the $b 14.0 per man-day level), and not in very large amounts. As a matter of fact, corn receives the lowest quantity of land allocation among the crops at all wage levels. All of the corn land allocated lies in Ichilo province.

Rice

The response of rice production to changes in wages is about the same as that of soybeans. At all the assumed wage levels, total rice production is at its maximum production constraint amount. The only change observed is a shift of the total rice production from hand to mechanized production when wages increase from $b 18.0 to 20.0 per man-day.

Yuca

Yuca production can compete more successfully with the other crops when wages are lower. At wages of $b 16.0 per man-day and above, yuca production falls to its minimum constraint in all provinces with a total of 4,528 hectares (Table 29). At wages of $b 12.0 per man-day and below, it reaches the maximum constraint of 8,410 hectares. The only intermediate figure recorded is 7,978 hectares at the $b 14.0 per man-day level.

Sugar cane

The production of sugar cane is at the milling capacity level when wages are at $b 14.0 per man-day or less, but as wages increase, land allocation to sugar cane production decreases. No land is allocated to sugar cane when wages are equal to $b 24 per man-day.

Since sugar cane production appears to be more sensitive to wage changes than all the other crops, it has to be concluded that it is relatively more labor intensive than the others.

CHAPTER IV

THE EFFECT OF THE DEVALUATION

Changes in Product Prices

The 67 percent devaluation of the Bolivian currency had an immediate and direct effect on domestic cotton prices since this crop is produced mainly for the export market. Having the prices of imported wheat and flour increased suddenly by 67 percent because of the devaluation, the Government was under heavy pressure to raise the prices paid to domestic wheat producers. It is assumed that the new price of wheat set by the Government would also be 67 percent higher than the pre-devaluation price.

As it was mentioned in Chapter I, there was a deficit of sugar cane production in 1971, when it become necessary to import about 40 percent of the total domestic consumption of the country, with a loss of foreign exchange of about 6 million dollars (U.S.). It is quite likely, therefore, that the Government would be willing to increase the domestic price in the same proportion as the cost of the alternative good: imported sugar. In view of this, sugar cane should be considered a crop whose price is directly affected by the devaluation, also.

At the time of the production survey in 1971, soybeans were considered a new crop, and no export market had been developed. A maximum production constraint has been set in the model based on the estimated domestic processing capacity.[38] It is assumed that at current prices, soybeans

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[38] The estimated domestic demand is based on the assumption that the oil processing plant will be built in the near future (see Chapter II).

production will satisfy all domestic consumption, particularly once the oil processing plant is built, thus providing the farmers a guaranteed market for their product.

At pre-devaluation prices, rice, corn, and yuca were produced only for domestic consumption, and it is assumed in the program that these prices increase only with the general level of prices in the food market.

The Analytical Approach

It must be assumed that the prices of all imported factors increased by the rate of devaluation, or 67 percent.[39] Of course, those inputs that are considered to be internally produced are also affected by the devaluation indirectly (cost-push inflation). The owners of labor services, for example, face higher prices of wheat, bread, flour, noodles, sugar, and the tools they utilize in work. Transport costs depend on the prices of vehicles, repair parts, labor for the driver and mechanics, and finally fuel prices. Fuel prices were maintained at the pre-devaluation level, but the price of the imported vehicles increased by 67 percent. The rate of increase in labor costs were probably somewhere in between, following the general level of wages.

The best assumption for transport costs seems to be that they increased with the general level of prices, with the changes of fuel and machinery prices tending to cancel each other.

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[39]It is true that all the domestic costs incurred in supplying or maintaining the imported factor (transport, handling, repairs, taxes, etc.) do not necessarily increase with the devaluation, but this will be ignored since a breakdown of such costs would probably not alter the calculations significantly.

Changes in Factor Prices

All custom costs for tractors, bulldozers, and combines were increased by 67 percent from $b 71.33; $b 253.0; and $b 131.03 per machine-hour to $b 119.12; $b 422.51; and $b 218.82 per machine-hour respectively. The custom cost of renting a hand seeder for rice production was raised from $b 32.0 to $b 53.44 per hectare. All chemicals and fertilizers are imported; their prices, therefore, were increased by the same proportion.

Once all the above price increments were introduced into the model, it was possible to assess the direction of changes in land allocation promoted by the new set of product and factor prices of the immediate post-devaluation period.

The sudden 67 percent increase in the above prices as a direct result of the devaluation, could not be isolated from the rest of the economy since practically all economic activities are dependent at least indirectly on foreign factors. It is expected, therefore, that other things being equal, all other product and factor prices should also start increasing as the impact of the first set of price increases spreads to the rest of the economy.

In order to allow for these expected increases in the rest of the prices, it is assumed in the post-devaluation model that all other product and factor prices increase simultaneously first by 20 percent and then by 40 percent. In the case of labor wages, this is accomplished by shifting vertically the entire supply curve by 20 and 40 percent. (This will be referred to as the 20 and 40 percent domestic price inflation.)

Program Results[40]

Soybeans

The 67 percent devaluation first makes it more profitable to produce soybeans by hand since mechanized production of soybeans has to compete with cotton and wheat for the limited amount of mechanically cleared land available. The 67 percent increase in cotton and wheat prices makes it possible for them to displace mechanized production of soybeans totally. But, as soon as the other prices respond to inflationary pressures, mechanized soybean land increases to 3,515 and 4,245 hectares at 20 and 40 percent of domestic price inflation.

Under all the devaluation and price inflation assumptions, soybeans are maintained at the maximum constrained production level of 528,000 cwt. The only observed changes are the shifts between mechanized and hand production techniques of soybean production mentioned above.

If no export market is developed, and the milling capacity remains at the estimated level, an excessive production of soybeans could be expected to generate downward pressure on the market price until the demand of the domestic market equals the supply.

Wheat

Wheat hectarage actually decreases slightly from 24,844 to 22,768 hectares even though its price has increased by 67 percent. The reason is that cotton takes over land formerly in wheat and soybeans. Wheat land is increased to 22,999 and 24,483 hectares when domestic prices are raised by 20 and 40 percent

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[40]The results are summarized in Table 49.

Table 49. Land allocation under different rates of domestic inflation, in hectares

Crops	Pre-de-valuation	Post-devaluation Domestic inflation, in percent 0	20	40
Land presently in use				
Summer mechanized soybeans	11,455	---	3,515	4,245
Summer hand soybeans	4,856	20,176	15,475	14,499
Winter mechanized soybeans	---	---	---	---
Cotton	41,385	50,560	49,325	48,595
Winter wheat	24,844	22,768	22,999	24,483
Corn	---	---	---	---
Mechanized rice	---	---	---	---
Hand rice	26,709	26,709	26,709	26,709
Yuca	7,978	7,978	7,978	7,978
Sugar cane	45,824	45,824	45,824	45,824
Newly cleared land				
Winter mechanized soybeans	---	---	---	---
Winter wheat	95,641	130,007	131,072	128,858
Cotton	240,935	231,760	232,995	233,725
Total cotton	282,320	282,320	282,320	282,320

Wheat planted in newly cleared land would increase from 95,641 to 130,007 hectares because of the 67 percent devaluation. This level is more or less maintained at the different levels of domestic inflation that have been assumed.

Cotton

Throughout this analysis of pre and post-devaluation prices combined also with 20 and 40 percent rates of domestic inflation, the total amount of land that the model assigns to cotton production remains constant at a value of 282,320 hectares (Table 49). Cotton is allocated the maximum possible amount of land under the assumed land constraints.[41]

The reduction of cotton production in newly clearing land due to the devaluation is only caused by a redistribution of the total cotton land in favor of cotton grown in land presently in use. The reason for such change is probably due to the additional 67 percent increase in the price of the fertilizer since it was assumed that no fertilizer is used for cotton unless it is cultivated on newly cleared land.[42]

Corn

Corn production cannot compete under any of the assumed sets of product and factor prices. Corn prices must be increased relative to all other prices in order to provide the necessary incentive for its production.

At post-devaulation and 40 percent domestic inflation prices, the model indicated that if corn prices increased from $b 29.65 to $b 31.65 per cwt, production would be initiated in the province of Ichilo.

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[41]Constraints on total cotton land in the provinces Sara, Ibáñez, and Ichilo. Constraints on cleared land for mechanized production, and total land to be cleared in the two remaining provinces: Santisteban and Warnes.

[42]Fertilizer application is very rarely observed at present, therefore, it is assumed in the model that no fertilizer is applied on the land presently in use. Instead, crop rotation or fallowing is carried out, although no regular pattern of crop rotation has been adopted in the area yet. It is also assumed in the model that all newly cleared land would be primarily assigned to large scale commercial production of cotton, with no provisions for crop rotation or fallowing. No estimates are available on the costs attributable to fallowing or impact of crop rotation on yields, but since they can be safely assumed to affect equally all crops grown in land presently in use, it is not necessary to include them in the analysis when comparisons are made among the crops in land presently in use. A shortcoming of the model is that while fertilizer costs are estimated for the newly cleared land, no equivalent cost estimate (for fallowing and/or crop rotation) is made for land presently in use.

The land allocated to corn would be 8,404 hectares with a total production of 419,685 cwt.

Rice

Rice remained at the maximum constrained land area throughout the analysis. All production was allocated to hand rice rather than mechanized rice. This indicated that the present production trend from large, mechanized farms to small plots cultivated by hand will be continued under the assumed price changes. These shifts have made additional mechanized land available for cotton production, particularly in the vicinity of the roads around Portachuelo and Montero which was formerly in rice production.

Yuca

The land allocation to yuca remains at the maximum level in all provinces except for Ibáñez. It is competing in the model with sugar cane, corn, and hand soybeans, but since sugar cane and soybeans remain at the maximum production level, yuca has to compete only with corn. When a 40 percent domestic price increase is assumed, additional land is allocated to yuca production in Ibáñez since hand soybeans are replaced by mechanized soybeans.

Sugar cane

Under all assumed prices, sugar cane production remains at the maximum milling capacity level. This would suggest that no further increases in sugar cane prices are necessary to maintain the mills at full capacity, but rather even a price reduction might be feasible.[43]

Labor requirements

The only significant change in labor demand observed under the different price assumptions is caused by the increase in cotton land from 41,385 to 50,560 hectares caused by the 67 percent devaluation previously discussed. This creates a larger demand for labor in period 2 (March and April), sufficient to intersect the labor supply function at a higher level. (The estimated labor supply function in the model increases stepwise.)

When the labor supply function is allowed to shift to reflect the effects of the assumed domestic inflation, no significant changes are observed in the equilibrium quantities of labor at each time period. As a result, equilibrium wages in each time period simply increase by 20 and 40 percent as domestic inflation is introduced in the model (see Table 50).

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[43]If sugar cane land allocation at the assumed prices was below full milling capacity levels, an alternative to increasing cane prices would be to eliminate the present quota system and give all potential suppliers the freedom to deliver this product to the mills. An additional obstacle to the efficient function of the free market could be uncertainty. This might be quite important to producers since most sugar cane production can last for 6 to 10 years. The government might find it advisable to guarantee not necessarily a totally fixed price, but rather a price that would not vary above certain percentage limits every year or every few years. This policy would then permit a reduction of price uncertainty while allowing a certain degree of adjustment between supply and demand.

Table 50. Total labor requirement, marginal factor cost, and wage level under different rates of inflation[a]

Time period	Pre-devaluation			Post-devaluation: Domestic inflation, in percent								
				0			20			40		
	man-days	MFC	Wage	man-days	MFC	Wage	man-days	MFC	Wage	man-days	MFC	Wage
1	2,226,427	15.5	15.0	2,685,779	15.5	15.0	2,588,425	18.6	18.0	2,569,153	21.7	21.0
2	7,977,444	23.0	20.0	8,280,973	24.5	21.0	8,262,468	29.4	25.2	8,257,598	34.3	29.4
3	8,561,011	24.5	21.0	8,642,525	24.5	21.0	8,649,542	29.4	25.2	8,657,055	34.3	29.4
4	1,342,962	14.0	14.0	1,374,320	14.0	14.0	1,366,533	16.8	16.8	1,373,478	19.6	19.6
5	3,048,533	17.0	16.0	3,259,085	17.0	16.0	3,194,969	20.4	19.2	3,187,954	23.8	22.4
6	3,214,370	17.0	16.0	3,213,802	17.0	16.0	3,213,878	20.4	19.2	3,218,540	23.8	22.4

[a]These values of marginal factor cost and wages refer only to those crops with an estimate of $b 14.0 per man-day of local or basic labor wages. Wage and MFC values are given in $b per man-day.

CHAPTER V

EXPORT TAXES ON COTTON

Some Basic Assumptions

The total demand for cotton comes both from the export and the domestic market. The quantity of domestic demand for the year 1972 has been estimated at a value of 100,000 cwt at a current price of US$ 717.4 per metric ton.[44]

For all practical purposes, the export demand facing Bolivian cotton producers can be assumed to be perfectly elastic at the world market price. No information is available on the price elasticity of the domestic demand curve. In view of this, it has been arbitrarily assumed that the domestic demand is perfectly inelastic.

Before any surpluses are available for export, the domestic price must be above the intersection of domestic demand and supply curves (i.e., excess supply must exist) and the domestic price will be equal to the world price minus transport costs and any export taxes. Changes in export taxes will thus have an effect on government revenues, and on producers and domestic consumers surpluses.

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[44]That is US$ 28.85 per cwt, which, deducting US$ 2.5 per cwt[45] for handling, transport, etc. leaves US$ 26.35 per cwt for the producer, which would be equal to the estimated pre-devaluation price of $b 350.0 per cwt at an exchange rate of $b 13.28/US$, which is more or less the free exchange rate that was prevalent at the time.

[45]W. Augusto Parra, "El Cultivo del Algodón en el Area de Santa Cruz y sus Necesidades de Capital para el Periodo 1972-73," p. 11.

DBC is the assumed domestic demand, OA the world market price minus transport costs, that determines the domestic price OA and the quantity of production OF. If production is reduced by one unit, the loss in producer's surplus would be equal to FE - FG = EG. The freed resources are allocated to the best alternative. This is also what the linear programming model does, EG is the reduction in the value of the objective function.

The gain in domestic consumer's surplus will be equal to the size of the tax per unit of production times the amount that is consumed, which is assumed to remain constant.

The size of the government revenues will equal the size of the tax per unit of production times the quantity that is exported.

In order to estimate the social cost to the country of the imposition of the export tax on cotton it is necessary to deduct the amount collected as tax and the gain in domestic consumer's surplus from the loss in producer's surplus.

The reliability of these estimates, of course, rests largely on the validity of the assumptions. While the assumptions might be challenged, they seemed to be appropriate, given the empirical techniques utilized and the data available. The least that can be said is that the results roughly approximate the net social cost of the tax.

Analytical Results

Table 51 shows the estimated supply response of cotton to increasing export tax rates. If a 40 percent tax is implemented, as was declared immediately after the devaluation, cotton production for exports would

Table 51. Cotton supply response to export taxes

Tax %	Price $b/cwt	Presently in use hectares	Presently in use cwt	To be cleared hectares	To be cleared cwt	Total hectares	Total cwt
0.00	584.5	48,595	624,447	233,725	3,003,365	282,320	3,627,812
14.46	500.0	48,595	624,447	233,725	3,003,365	282,320	3,627,812
18.73	475.0	36,297	466,423	215,056	2,763,472	251,353	3,229,895
23.01	450.0	36,271	466,079	176,980	2,274,192	213,251	2,740,271
27.29	425.0	36,301	466,462	64,585	829,918	100,886	1,296,380
31.57	400.0	36,301	466,462	---	---	36,301	466,462
35.84	375.0	23,826	306,168	---	---	23,826	306,168
40.12	350.0	---	---	---	---	---	---

be discouraged completely. There would be enough production only to satisfy the domestic demand for it.

The production of cotton is not affected at all by the export tax until the price reduction reaches values above 14.46 percent (Table 51). If the tax is set at 31.57 percent, the clearing of additional land for cotton production is no longer feasible. Table 52 shows that the net income of the agricultural producers can vary all the way from 719 millions of $b with no export tax, to 161 millions with a 40.12 percent tax that would make cotton production economically infeasible.[46]

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[46]Here the model is simply estimating points on the supply curve. If left uncontrolled, the domestic price could not fall below the level of the intersection between domestic supply and demand.

Table 52. Impact of cotton export taxes on total net profits of the agricultural producers, and government revenues

Percent tax rate	Net price $b/cwt	Production cwt	Net profits ($b.000)	Gain in domestic consumer's surplus ($b.000)	Government tax ($b.000)	Net social benefits ($b.000)
0.00	584.5	3,627,812	719,318	---	---	719,318
14.46	500.0	3,627,812	412,768	8,450	298,100	719,318
18.73	475.0	3,229,895	327,699	10,950	342,724	681,373
23.01	450.0	2,740,271	249,172	13,450	355,116	617,738
27.29	425.0	1,296,380	195,170	15,950	190,823	401,943
31.57	400.0	466,462	171,866	18,450	67,612	257,928
35.84	375.0	306,168	161,556	20,950	43,192	225,698
40.12	350.0	---	160,510	---	---	160,510

The export tax creates a misallocation of resources by distributing land, labor, and the other factors of production in a manner other than optimum. Table 53 indicates the land allocation resulting from different tax rates, and Table 54 shows the changes that occur in the labor market.

If the tax is set at that level which maximizes government revenues, the tax rate should be about 23 percent. Higher tax rates would reduce the quantity produced so much that the total tax collected would be lower.

The total cost to the country of implementing a 23 percent tax on cotton exports has been estimated as follows: the gain in consumer's surplus is equal to the amount consumed domestically times the price drop

Table 53. Land allocation under different cotton export tax rates, in hectares

	Percent tax rate							
	0.00	14.46	18.73	23.01	27.29	31.57	35.84	40.12
Net cotton prices ($b/cwt)	584.5	500.0	475.0	450.0	425.0	400.0	375.0	350.0
Land presently in use								
Summer mechanized soybeans	4,245	4,245	15,086	15,086	15,086	15,086	15,086	15,086
Summer hand soybeans	14,499	14,499	---	---	---	---	---	---
Winter mechanized soybeans	---	---	---	---	---	---	---	---
Winter wheat	24,483	24,483	50,945	51,026	50,936	50,936	51,649	52,840
Cotton	48,595	48,595	36,297	36,271	36,301	36,301	23,826	---
Corn	---	---	---	---	24,029	24,029	36,861	60,596
Mechanized rice	---	---	---	---	---	---	---	---
Hand rice	26,709	26,709	26,692	26,709	26,705	26,705	26,336	26,430
Yuca	7,978	7,978	7,978	8,410	8,410	8,410	8,410	8,410
Sugar cane	45,824	45,824	45,824	45,724	45,724	45,724	45,724	45,724
Newly cleared land								
Winter soybeans	---	---	---	---	---	---	---	---
Winter wheat	128,858	128,858	185,486	152,645	55,705	---	---	---
Cotton	233,725	233,725	215,056	176,980	64,585	---	---	---

Table 54. Labor market equilibrium under different cotton export tax rates, for each time period

Time period	Percent tax rate 0.00	14.46	18.73	23.01	27.29	31.57	35.84	40.12
Net cotton price ($b/cwt)	584.5	500.0	475.0	450.0	425.0	400.0	375.0	350.0
1 man-days	2,564,340	2,564,340	2,460,535	2,199,342	1,657,199	1,205,540	1,292,300	1,453,372
MFC ($b/MD)	21.7	21.7	21.7	21.7	19.6	19.6	19.6	19.6
wage($b/MD)	21.0	21.0	21.0	21.0	19.6	19.6	19.6	19.6
2 man-days	8,251,990	8,251,990	8,035,843	6,977,444	3,977,444	2,172,752	1,977,444	1,596,578
MFC ($b/MD)	34.3	34.3	34.3	30.1	23.8	21.7	19.6	19.6
wage($b/MD)	29.4	29.4	29.4	26.6	22.4	21.0	19.6	19.6
3 man-days	8,648,163	8,648,163	8,108,820	7,053,788	4,030,905	2,227,031	1,975,248	1,487,512
MFC ($b/MD)	34.3	34.3	34.3	32.2	25.9	21.7	19.6	19.6
wage($b/MD)	29.4	29.4	29.4	28.0	23.8	21.0	19.6	19.6
4 man-days	1,364,773	1,364,773	1,328,905	1,299,981	1,345,585	1,281,757	1,356,323	1,492,471
MFC ($b/MD)	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
wage($b/MD)	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
5 man-days	3,181,629	3,181,629	2,830,477	2,640,834	2,388,050	2,055,774	2,164,094	2,366,010
MFC ($b/MD)	23.8	23.8	21.7	21.7	21.7	21.7	21.7	21.7
wage($b/MD)	22.4	22.4	21.0	21.0	21.0	21.0	21.0	21.0
6 man-days	3,213,923	3,213,923	2,957,269	2,645,425	2,033,478	1,496,970	1,562,944	1,684,639
MFC ($b/MD)	23.8	23.8	21.7	21.7	21.7	19.6	19.6	19.6
wage($b/MD)	22.4	22.4	21.0	21.0	21.0	19.6	19.6	19.6

(100,000 cwt x 134.5 \$b/cwt = 13.45 millions of \$b), the government tax revenues equal the amount exported times the tax per unit (2,640,271 cwt x 134.5 \$b/cwt = 355.12 millions of \$b), the loss in producer's surplus estimated by the reduction in the total net benefits to the agricultural producers is equal to 470.15 millions of \$b. The net social loss is 470.15 - 13.45 - 355.12 = 101.58 millions of \$b.

The "external pecuniary economies" caused by the reduction in cotton production are evident in Table 54. As a result of a lower total demand for labor, wages for each of the time periods are gradually reduced as the export tax on cotton is increased. This price decrease in a factor of production plus the release of land previously used for cotton makes it feasible to increase the amount of land devoted to other crops as the export tax increases.

Corn production becomes competitive when the taxes on cotton are above 27.29 percent. Land for wheat production is doubled when the tax is increased from 14.46 to 18.73 percent. All the other crops remain at their maximum production levels throughout the range of cotton export taxes considered.

CHAPTER VI

PRICE POLICIES REQUIRED TO REACH SELF-SUFFICIENCY IN WHEAT PRODUCTION

It has been noted already by several researchers (Gardner, 1970; Lucio Arze, 1970; Wheat Institute, Bulletin 1, 1972; Gómez et al., 1972) that any major increase in the total production of wheat would most probably result from new areas open to wheat production in eastern Bolivia. Two of the above (Gardner, and Arze) have mentioned the Abapó-Izozog project specifically, as an alternative, but one requiring also a sizeable initial investment in infrastructure mainly for irrigation.[47]

Therefore, since at present the Abapó-Izozog project has not been implemented, and since the traditional wheat producing areas engaged in a subsistence type of agriculture are very slow in accepting the introduction of new technologies and/or responding to economic incentives because of the high cost of risk and strong preferences against uncertainty, it is only logical to turn to Santa Cruz as the most promising area if self-sufficiency is to be reached in the next five to ten years.

Wheat Supply Response

As the price of wheat is increased in the model, the quantities produced increase until a maximum of 4.84×10^6 cwt is reached at the

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[47] B. Delworth Gardner, The Economics of an Increase in Wheat Production in Bolivia, Utah State University, RDD, Usaid/Bolivia, USU Series 13-66, May 1966, pp. 27-33.

$b 100 per cwt price. No further response is noted even if the price is increased to $b 150 per cwt (Table 55). The reason is that wheat production has reached the land constraints in all five provinces, and the estimated maximum physical capacity level has been attained in the area.

Wheat production in the entire country has been estimated at 1,326, 715 cwt in 1971;[48] and total consumption at 8,045,400 cwt, at prices of $b 46.0 and 52.0 per cwt paid for criollo and hard wheat respectively at the flour mills.[49] After deductions have been made for hectolitric weight and impurities, it was estimated that the average price received by the wheat producers in Santa Cruz department would be $b 46.75 per cwt.[50]

After the 67 percent devaluation of the currency, and 40 percent increase in domestic factor prices have worked out, it is roughly estimated that the general level of prices in the economy has increased by about 50 percent. It is assumed that the price of wheat has followed this trend in inflation (50 percent increase), i.e., from $b 46.75 to $b 70.12 per cwt.

It is assumed, therefore, that the above estimates of domestic wheat production and total consumption still hold at the adjusted price of $b 70.12 per cwt after the devaluation, and a 40 percent price increase in the domestic factors used for agricultural production.

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[48] Enrique Gómez, et al., Wheat study, Ministerio de Agricultura y Ganadería, Utah State University, Usaid/Bolivia, October 1972, Table 43.

[49] Ibid., Table 44.

[50] From Table 62, Appendix A.

Table 55. Wheat supply response to increased prices

Price	Land presently in use		Newly cleared land		Total	
$b/cwt	hectares	cwt	hectares	cwt	hectares	cwt
70.12	24,483	489,667	---	---	24,483	489,667
78.07	24,483	489,667	128,858	2,577,152	153,341	3,066,819
80.00	24,483	489,667	128,858	2,577,152	153,341	3,066,819
85.00	22,999	459,980	131,072	2,621,439	154,071	3,081,419
90.00	23,360	467,190	137,291	2,745,813	160,651	3,213,003
95.00	23,360	467,190	137,291	2,745,813	160,651	3,213,003
100.00	50,519	1,010,374	191,705	3,834,094	242,224	4,844,468
150.00	50,519	1,010,374	191,705	3,834,094	242,224	4,844,468

The supply function for wheat in the traditional areas has been estimated by applying an assumed price elasticity of 1.0 to the benchmark point of 1,326,715 cwt at $b 70.12 per cwt.

The Demand for Wheat and Its Intersection with Supply

No information is available on the total demand function except long term projections that, at best, take into account the effect of changes in per capita real income and total population. As was discussed earlier, it is from one of these sources that the 8,045,400 cwt estimate was made at the adjusted price of $b 70.12 per cwt.

No estimates of price elasticity of demand are available for Bolivia, but an estimated -0.24 price elasticity of demand for cereals in Perú has been taken as a rough approximation.[51] It is the only neighboring country that can be reasonably compared with Bolivia. At least the eating habits and preferences of their native populations are similar. (The estimates of the size of the native populations in Perú and Bolivia are between 60 percent and 70 percent of their total populations.) The estimated total demand curve appears in Table 56. (If the price is increased by 80 percent, to $b 126.22 per cwt, consumption is decreased to 6,500,683 cwt.)

It was intended at the beginning of this study that supply elasticities of 1.0; 0.9; and 0.8 would be assumed for the traditional areas, but only the first one has been utilized because the other two do not produce any significant changes in the results obtained.

The demand curve faced by Santa Cruz producers has been estimated by subtracting from the total demand function the quantities to be supplied by the traditional wheat producing areas at each alternative price. It intersects the supply function at an estimated equilibrium price of $b 111.0 per cwt (see Figure 11). At this point, wheat production in the traditional areas would be at about 2.10×10^6 cwt). The equilibrium between total supply and demand would be at quantity 6.94×10^6 cwt (see Figure 11).

The problem can be posed the following way. Suppose we examine the price subsidies to wheat production needed to attain self-sufficiency

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[51]Hylke Van de Wetering, Perú, long term projections of demand for and supply of selected agricultural commodities through 1980, Economic Research Service of the US Department of Agriculture, June 1969, pp. 64-65.

Table 56. Total domestic demand under different prices

Price $b/cwt	Percent change	Quantity cwt	Percent change
70.12	0	8,045,400	0.0
77.13	10	7,852,310	- 2.4
84.14	20	7,659,221	- 4.8
91.16	30	7,466,131	- 7.2
98.17	40	7,273,042	- 9.6
105.18	50	7,079,952	-12.0
112.19	60	6,886,862	-14.4
119.20	70	6,693,773	-16.8
126.22	80	6,500,683	-19.2

while at the same time the prices paid by the consumers are held constant.[52] Thus, the relevant total demand curve would be perfectly inelastic at the 8,045,400 cwt present consumption level. The demand curve facing the Santa Cruz producers can be obtained in the same fashion as discussed earlier. The results (illustrated in Figure 12) indicate that for prices above $b 100.0 per cwt, no additional supply can be obtained from the Santa Cruz area because the production of wheat has reached land constraints in each of the five provinces.

[52]To increase wheat and/or flour prices is a potentially explosive issue because of the political unrest that it can cause. B. Delworth Gardner, The Economics of an Increase in Wheat Production in Bolivia, Utah State University, RDD, Usaid/Bolivia, USU Series 13-66, May 1966, p. 51.

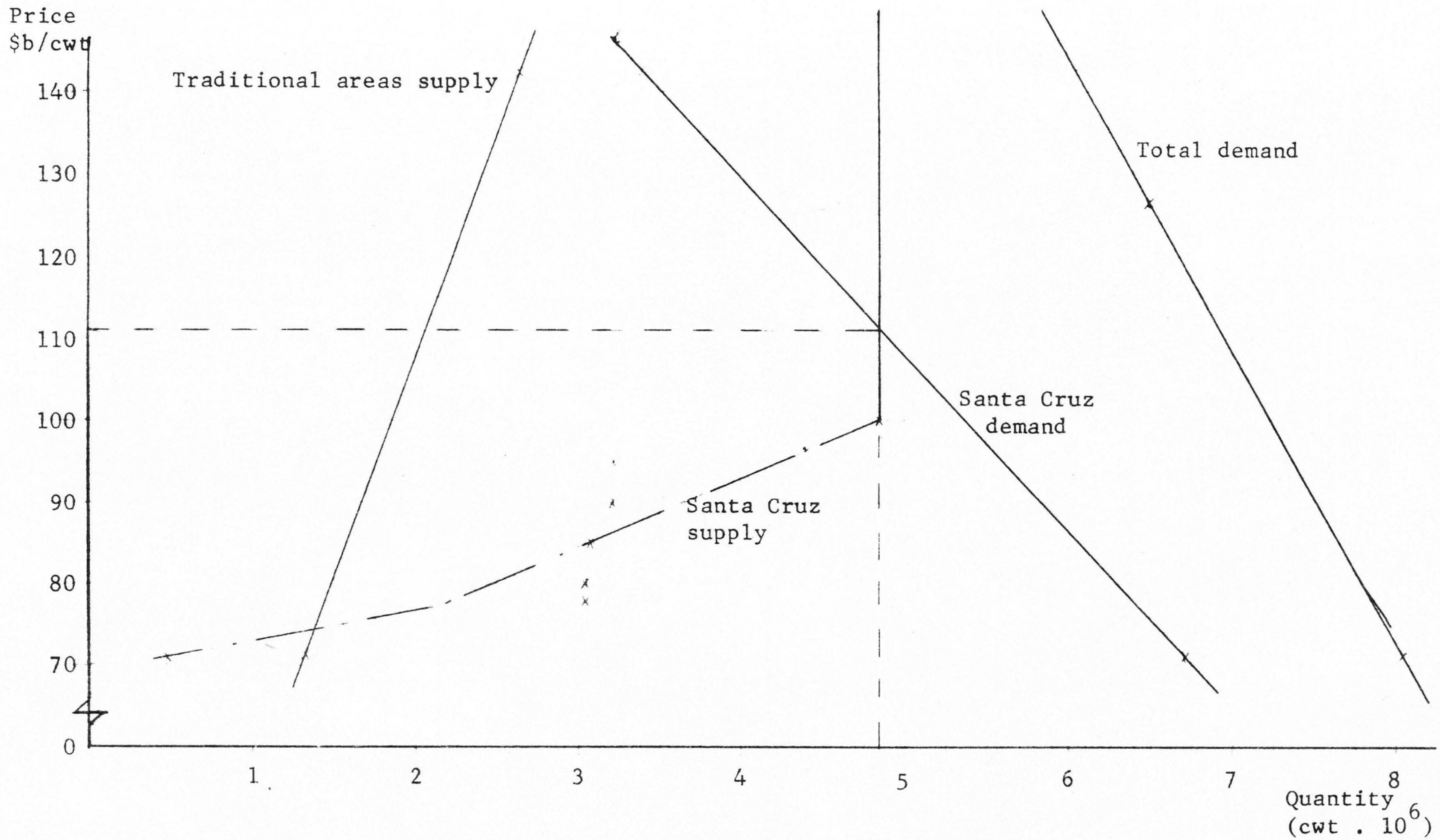

Figure 11. Wheat demand and supply estimates

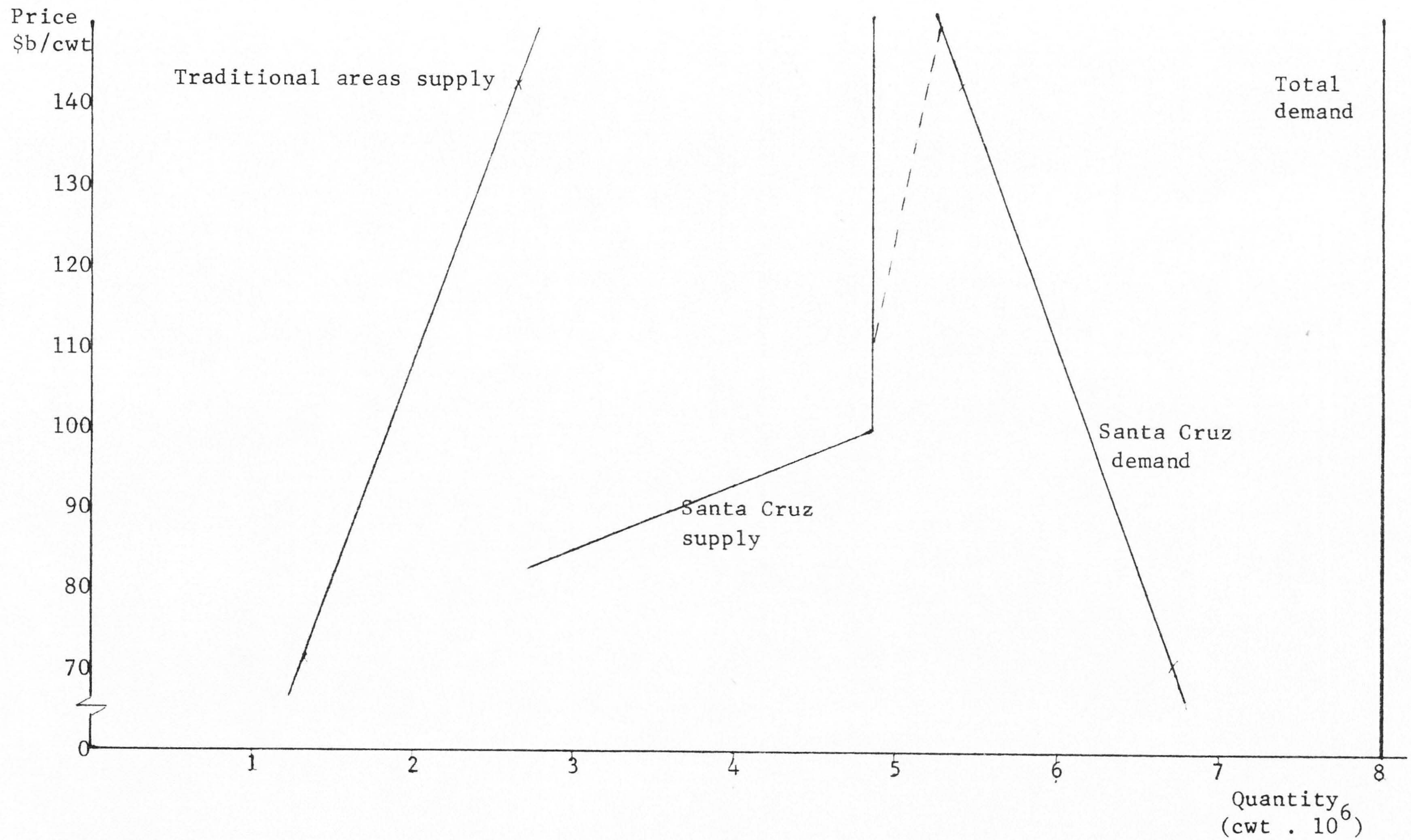

Figure 12. Wheat demand and supply estimates when a price subsidy to consumers is in effect.

Therefore, the deficit of about 1.33 x 10^6 cwt at \$b 100.0 per cwt can be reduced only by encouraging more production in the traditional areas through even higher prices. It is not reasonable, therefore, to expect that increased wheat production in the Santa Cruz area alone can achieve self-sufficiency national levels. The nation must look also at the traditional wheat areas, for new areas, or reduce consumption by permitting wheat and flour prices to rise.

The Price Subsidy and Social Welfare

Even though the supply curve in the model did not equal demand even at the highest prices assumed, as a government subsidy is implemented (Figure 12), we can assume that the supply function can be further extrapolated until it intersects demand at a \$b 150.0 per cwt price (broken line, Figure 12). If the government desires to maintain a constant wheat price of \$b 70.12 per cwt for the consumers, while attaining self-sufficiency in production, the subsidy has to cover the gap between \$b 150.0 and \$b 70.12 per cwt. In consequence, a subsidy of \$b 79.88 per cwt (113.92 percent) would need to be paid for a domestic production of 8,045,400 cwt, with a total expenditure of \$b 642.66 millions annually.

Since the wheat supply curve for the traditional areas has been assumed to be unitary elastic, the quantity supplied would increase also by 113.92 percent, or from 1,326,715 to 2,838, 109 cwt. The gain in producer's surplus in the traditional areas would be approximately 166.34 millions of pesos bolivianos.

The gain in producer's surplus in the Santa Cruz area is calculated in two steps. Firstly, it is identified with the increase in total net returns to the agricultural producers as wheat prices are raised from $b 70.12 to 111.0 per cwt; that is, the increase in the value of the objective function in the program. The value of the objective function increased from 704.61 to 843.72 millions of $b, which represents a net increase of 139.11 millions of $b. Secondly, the remainder is calculated geometrically by moving along the assumed supply curve (dotted line, Figure 12) when the price is increased from $b 111.0 to $b 150.0 per cwt. This gain in producer's surplus is estimated to be 196.0 millions of $b. The total gain in producer's surplus in the Santa Cruz area, that results from the rise in wheat prices from $b 70.12 to 150.0 per cwt is thus 139.11 + 196.00 = 335.11 millions of $b.

In order to assess the overall impact of the price subsidy on total welfare, the government expenditure of 642.66 millions of $b must be weighed against the total gain in producer's surplus both in the traditional areas and in Santa Cruz. (335.11 + 166.34 = 501.45 millions of $b.) No change in consumer's surplus exists since the real price and the quantity consumed are assumed to remain constant as the result of implementing the price subsidy. The net social cost of implementing a program of self-sufficiency in wheat production without an increase in the price paid by the consumers is estimated by substracting the total gain in producer's surplus from the government expenditure in the price subsidy: 642.66 - 501.45 = 141.21 millions of $b.

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APPENDIXES

Appendix A

Costs of Production Estimates

Data Collection

The results shown here have been obtained through a questionnaire survey. The survey was made by a team composed of members of the offices of Statistics and Planning at the Ministry of Agriculture in Bolivia, extension agents, and the author of this thesis. The work was carried out in the months of June and July in 1972, although some additional questionnaires were completed later by the two extension agents that work in the area. At first, it was attempted to conduct the survey following a random sampling method in the selection of the interviewees. The result was that more than 70 percent of the randomly selected farmers could not be interviewed either because they refused to cooperate or were unable to provide the necessary information. It became obvious that a sample obtained under these circumstances could not be considered to be a random one.

The total number of questionnaires collected was 233, distributed mainly among the 7 most important crops and four types of land clearing methods. The seven crops studied are: sugar cane, wheat, cotton, rice, corn, yuca, and soybeans. A few of the collected questionnaires covered other crops such as tomatoes, potatoes, pineapple, etc., that have not been included because they cover a negligible proportion of the total agricultural land in the area.

All land clearing procedures were classified among four different land clearing techniques following the terminology currently used in the area and also used by the Ministry of Agriculture in its annual rice production surveys.

The first two are: mechanized land clearing and hand land clearing. Both are applied to plots never cleared before or left to fallow for a period of over four years, so that relatively high trees must be cleared. In the mechanized method the tree stumps are removed with the use of caterpillars, and then the land is levelled and plowed with tractors. In the hand method the trees are burned once the bushes have been removed. The tree stumps remain in the soil, so that no further cultivation with tractors is possible for at least 4 years.

The second two refer to land clearing of plots with only small trees and/or bushes. They can be either natural pasture land or young fallow land. The hand method, which includes bush clearing, burning, and clearing is called "fallowing." The other one also includes tractor plowing and levelling and is called "plowing."

Data Processing

The number of observation obtained for each operation in the production costs varies because some of the questionnaires left certain questions unanswered or partly answered. In addition, some of the answers obtained have been rejected. The reason behind it is that some farmers might have given wrong answers or the interviewer may have committed a mistake in writing down the answer.

Since the sample was not random, it could be the case that a few of the interviewed farmers followed practices totally different from the rest, and if included in the calculations could significantly bias the estimates of the means. In order to decide which figures should be rejected, it was assumed that all the parameters were distributed following a normal distribution. All the observations outside a 99 percent confidence interval [$\bar{X} \pm t$ $(.995, n-2) \cdot S_X$] were rejected.

New estimates were made of the mean ($\bar{X}$) and the standard deviation of the X's (S_X). These estimates appear in Tables 1 to 11, and cover each operation carried out in each one of the four different methods of land clearing and cultivation of the seven crops. The number of observations (n) on which is based the calculation of each parameter, is also indicated. In some cases n is very small and even equal to one. In such cases, additional sources of information, and excercising of subjective judgement will be required in order to make the final estimates of the coefficients of productions to be used in the linear program.

Separate tables have been made showing the number of interviewed farmers that carried out each opperation at a given time. For these purposes, the year has been divided into six periods of two months each.

It has been assumed that these frequency distributions follow a normal function.[53] Estimates have been made of the mean and the variance of the X's. It was observed that the estimates of the means can vary by assuming that the observations in the last period of the year were made actually in the year before and thus belong to the opposite end of the time distribution, or vice versa.

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[53]A test for normality was not applied because of the low number of points along the X's axes.

In order to eliminate elements of arbitrariness, the mean estimate ($\bar{X}$) with the smallest variance was chosen, with the assumption that it would constitute the best estimator of the population mean.

The symbols used in the tables are:

n : number of observations in the sample

$\bar{X}$: mean value of the sample

S_X : standard deviation of the X's

Ha : hectarea, equal to 10^4 m^2

MD : man-days

MH : machine-hours

\$b : Bolivian pesos

cwt: hundredweight, equal to 100 lb

MT : metric tons

Analysis of the Results

Daily wages

Due to seasonal shifts in the demand and/or supply of labor for agriculture, wages paid to the hired labor in agriculture might also vary during the year. In order to check this, all the daily wages data were arranged in six time periods, of two months each, and a test was made to verify the hypothesis of equality of means for all the time periods.[54] The results of the test failed to reject the hypothesis (see Table 71). One assumption implied in the analysis is that of equal variances of the

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[54] From Bernard Ostle, "Statistics in Research," (Ames, Iowa: Iowa State University Press, 1969).

samples, but this assumption is not critical at all,[55] therefore no tests to verify the homogeneity of the variances was applied, and have not been applied throughout this appendix.

The next step was to see if the wages for all the crop operations are significantly different. A hypothesis of equality of means was examined with the following results:

Hypothesis: $\mu_1 = \mu_2 = \ldots\ldots\ldots = \mu_k$

$$\bar{X} = 13.19 \text{ \$b/MD}; \quad n = 325; \quad k = 37$$

$$\sum_{i=1}^{k} n_i (\bar{X}_i - \bar{X})^2 = 323.16; \quad \sum_{i=1}^{k} \sum_{j=1}^{n_i} (X_{ij} - \bar{X}_i)^2 = 1{,}654.25$$

$$F = \frac{\sum_{i=1}^{k} n_i (\bar{X}_i - \bar{X})^2}{\sum_{i=1}^{k} \sum_{j=1}^{n_i} (X_{ij} - \bar{X}_i)^2} \cdot \frac{(n - k)}{(k - 1)} = 1.56$$

Tabulated value $F_{(36;288;.95)} = 1.42$

Since the calculated value was higher than the tabulated one, the hypothesis was rejected and it was concluded that the daily wages paid for the different operations are significantly different.

This result was to be expected. The level of technology applied to certain crops is different, particularly in the case of cotton where more modern techniques are employed. The quantity of fixed capital

[55] Consulted with Dr. Donald Sisson, Department of Applied Statistics and Computer Science, Utah State University.

invested in the form of better land clearing methods applied to the land, and agricultural tools, will also have an impact on the marginal productivity of any other input, and thus on the payments going to these factors of production. But wages paid for the different operations within each crop might not be significantly different. To verify this, all the operations were grouped by crops, with an additional group for all the land clearing operations. Separate tests of equality of means were run, the results appear on Tables 72 to 75.[56] Since none of the hypotheses of equality of means was rejected, the results lent support to the belief that even though salaries paid in all crop operations are not the same, they are not significantly different for the operations performed within a given crop or belonging to the land clearing operations group.

The relevant question, therefore, is whether laborers tend to get paid higher wages when working in certain crops rather than in others. An equality of means test was run for the average wages paid in each one of the seven crops plus land clearing operations. The hypothesis of equality of average wages was rejected (see Table 76). It was noticed that wages paid in cotton, sugar cane, and soybeans were consistently higher than in the other crops. Tests were conducted (Table 77) to verify the hypothesis of equality of wages paid for cotton, soybeans, and sugar cane production, in one group and wheat, rice, corn, and yuca production, and land clearing practices in another. In both cases the

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[56] All X's are equal to 12.00 $b/MD in all the operations in wheat production, therefore no test was necessary.

hypothesis of equality of means (average wages) within the group failed to be rejected.[57]

Custom rates on tractor operations

The average figures obtained are the custom rates charged for the operation of tractors[58] in several different tasks in land clearing as well as crop production. A test for equality of means was run, and the results appear in Table 78. These results do not show the rates to be significantly different from one operation to another, therefore, a common rate equal to the total weighted average will be assumed.

Fixed investment on the land

Since there is practically no irrigated land in the area, and very limited amounts of investment in land improvements other than land clearing, the difference between the prices of cleared and uncleared land in a given location, other things being equal, should be equal to the cost of the land clearing method used. This relationship will make it possible to crosscheck the accuracy of the estimates obtained for the costs of the land clearing operations.

The underlying assumptions here are, first, that the samples collected of the land prices for uncleared land (virgin as well as fallow land abandoned for more than four years) and land cleared mechanically or by hand are all representative of their respective populations, or if biased, are all equally biased so that the differences between them are

[57]For a discussion on the difference between the two groups, see Chapter II.

[58]The tractors are mostly about 50 HP, and the rate includes the wages paid to the tractor driver and his assistant.

not affected. The second assumption is that, on the average, there are no significant differences in regards to things such as market infrastructure, and soil properties. The only differences, therefore, would be those that have originated from the land clearing procedure or the usage and wearing out of the soil.

Since the samples may have too many observations of land prices in certain provinces relative to others, or too many observations in some crops relative to others, a bias could have been introduced if land prices vary significantly from one province to the other and/or one crop to another. In order to verify this, a separate analysis was made for each one of the four land classifications. Two hypotheses were checked: equality of means for the land prices in the different provinces, and equality of means for the land prices among the different crops[59] (see Tables 79 to 82).

Out of the eight tests performed none of them showed statistically significant differences among the mean land prices ($b/Ha) collected either for the different provinces or crops at the 99 percent probability level. Only in three instances was the equality of means hypothesis rejected at the 95 percent probability level. Therefore, the differences between the general averages estimating the land prices of cleared and uncleared land will be used as a first approximation to estimate the value added to the land by means of land clearing, either by hand or mechanically, and the reduction in the value of the land when it has been used and left to fallow.

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[59]In order to find out the land price of uncleared land, the farmer was asked about the price commanded by an uncleared plot of similar soil in the area.

An equality of means test was used to see if the average land prices of uncleared and fallow land are significantly different. The results appear in Table 83 and show no significant difference, therefore, uncleared and fallow land will be considered to have the same average price.[60]

Table 84 summarizes the results obtained from Tables 79 to 83. The results indicate an average gain in the value of the land equal to 496.68 $b/Ha when it is cleared by hand, and 2,186.22 $b/Ha if it is cleared mechanically.[61]

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[60] During the survey, fallow land was defined as land not in use for a period of over 4 years.

[61] The mechanized procedure is superior to the hand one in that it clears the land of all tree stumps, and levels and plows the soil surface.

Table 57. Mechanized land clearing costs per hectare

Operation		n	$\bar{X}$	S_x
Bulldozer tree clearing				
	MH/Ha	5	5.12	3.07
	\$b/MH	4	256.50	53.63
	\$b/Ha	10	1,385.20	735.21
Plowing[a]				
	MH/Ha	5	2.20	0.57
	\$b/MH	2	42.50	10.61
	\$b/Ha	9	165.11	66.62
Levelling[a]				
	MH/Ha	7	2.57	0.98
	\$b/MH	4	96.25	49.90
	\$b/Ha	8	226.25	101.55
Total				
	MH/Ha	7	9.43	1.90
	\$b/Ha	10	2,099.90	1,139.30

[a]These custom costs include the salaries paid to the driver and one assistant.

Table 58. Hand land clearing costs per hectare

Operation		n	$\bar{X}$	S_x
Brush clearing				
	MD/Ha	11	13.73	3.44
	$b/MD	11	13.18	2.40
	$b/Ha	15	161.60	60.02
Tree clearing				
	MD/Ha	10	20.30	9.80
	$b/MD	9	14.00	4.58
	$b/Ha	14	280.50	114.40
Burning and cleaning				
	MD/Ha	33	4.84	3.42
	$b/MD	32	12.50	1.67
	$b/Ha	60	78.70	46.21
Total	MD/Ha	28	32.25	13.54
	$b/MD	25	14.92	3.77
	$b/Ha	96	467.84	97.15

Table 59. Fallow land clearing costs per hectare

Operation		n	$\bar{X}$	S_x
Brush clearing				
	MD/Ha	7	10.57	3.05
	$b/MD	7	15.57	2.94
	$b/Ha	22	222.73	70.13
Burning and cleaning				
	MD/Ha	12	2.22	1.31
	$b/MD	11	13.45	2.02
	$b/Ha	27	73.41	46.30
Total	MD/Ha	7	14.14	6.39
	$b/MD	7	15.14	2.85
	$b/Ha	34	332.47	104.44

Table 60. Plowing land clearing costs per hectare

Operation		n	$\overline{X}$	S_x
Hand tree clearing				
	MD/Ha	5	74.64	56.47
	$b/MD	5	14.40	2.51
	$b/Ha	19	870.63	456.76
Plowing	MH/Ha	8	2.88	1.90
	$b/MH	5	98.20	31.66
	$b/Ha	15	326.33	75.89
Levelling	MH/Ha	8	2.27	0.98
	$b/MH	5	71.60	21.69
	$b/Ha	14	243.21	150.10
Total	$b/Ha	14	1,297.29	458.66

Table 61. Sugar cane costs of production, per hectare

Operation		n	$\overline{X}$	S_x
Land preparation				
	MD/Ha	3	14.33	13.65
	$b/MD	3	12.67	2.08
	$b/Ha	14	206.36	133.91
Planting[a]	MD/Ha	21	22.29	4.85
	$b/MD	11	14.36	1.43
	MT/Ha of seed	64	4.66	0.80
	$b/MT seed	39	42.21	10.96
	$b/Ha[b]	77	384.39	64.76
	MH/Ha seed transport	10	3.74	0.42
First weeding				
	MD/Ha	21	10.14	1.24
	$b/MD	21	14.00	1.73
	$b/Ha	77	136.75	19.70
Second weeding				
	MD/Ha	19	10.00	2.31
	$b/MD	18	13.50	2.31
	$b/Ha	78	132.18	19.98
Third weeding				
	MD/Ha	10	10.40	0.97
	$b/MD	10	13.00	2.40
	$b/Ha	56	134.55	25.21
Harvesting	MD/MT	10	0.84	0.28
	MD/Ha	10	41.40	14.10
	$b/MD	8	15.62	2.87
	$b/MT	72	15.12	0.99
	$b/Ha	70	788.56	274.39
Transport to the mill				
	MH/trip to Guabirá	3	5.67	4.04
	$b/MT id.	41	18.43	3.93
	MH/trip to La Bélgica	1	4.00	----
	$b/MT id.	27	26.55	5.80
	MH/trip to San Aurelio	2	13.00	12.73
	$b/MT id.	20	27.85	3.08
	$b/MT "unspecified"	21	16.48	5.44

Table 61. Continued

Operation		n	$\bar{X}$	S_x
Yield				
MT/Ha first year crop		44	55.43	18.24
Mt/Ha following years		34	44.59	16.63
Price at the mill	\$b/MT	23	70.65	3.10
Fees to the union of growers	\$b/MT	4	2.26	1.19
Land prices				
uncleared land	\$b/Ha	53	353.36	197.83
fallow land	\$b/Ha	36	320.14	202.91
hand cleared land	\$b/Ha	6	825.00	629.09
mechanically cleared land	\$b/Ha	6	2,700.00	894.43

[a]It includes cutting and cleaning the seed

[b]The seed value is not included

Table 62. Wheat costs of production, per hectare

Operation	n	$\bar{X}$	S_x
Land preparation			
MD/Ha	2	13.00	1.41
$b/MD	2	12.00	0.00
$b/Ha	2	156.00	16.97
Seeding			
MD/Ha (with hand seeder)	2	3.75	0.35
MH/Ha (with tractor)	4	0.95	0.70
$b/MH	2	41.00	8.49
$b/Ha[a]	10	77.90	32.17
cwt/Ha seed	9	1.82	0.60
$b/cwt of seed	10	78.20	8.31
First weeding			
MD/Ha	2	10.00	0.00
$b/MD	2	12.00	0.00
$b/Ha	3	120.00	0.00
Second weeding			
MD/Ha	1	10.00	----
$b/MD	1	12.00	----
$b/Ha	1	120.00	----
Treatments			
MD/Ha hand spraying	1	0.10	----
MH/Ha tractor spraying	1	0.20	----
$b/Ha chemicals	3	6.90	3.00
$b/Ha application	2	11.00	12.73
Harvesting			
MD/Ha hand harvesting	2	7.00	8.49
MH/Ha combine harvesting	3	1.60	0.40
$b/MH	3	91.00	57.56
$b/Ha[b]	8	215.25	110.67
Marketing			
cwt/Ha yield	4	13.65	4.89
$b/cwt transport to Santa Cruz	4	1.82	0.24
$b/cwt price received	4	46.75	7.89

Table 62. Continued

Operation	n	$\bar{X}$	S_x
Land prices			
$b/Ha uncleared land	8	406.25	376.49
$b/Ha fallow land	8	475.00	373.21
$b/Ha mechanically cleared land	4	3,750.00	2,217.36

[a]The value of the seed is not included

[b]Includes loading and handling

Table 63. Cotton costs of production, per hectare

Operation	n	$\bar{X}$	S_x
Land preparation			
MH/Ha	9	5.43	2.67
$b/MH	6	90.83	40.90
$b/Ha	16	491.25	153.79
Seeding			
MD/Ha (hand seeding)	3	2.93	1.10
$b/MD	2	16.00	5.66
MH/Ha	7	0.72	0.23
$b/MH	4	72.00	8.12
$b/Ha	17	73.82	18.65
lb/Ha seed	21	27.95	5.19
$b/lb of seed	13	7.38	2.51
Thinning			
MD/Ha	2	4.00	0.00
$b/Ha	8	79.25	33.70
Hand weeding			
MD/Ha	6	11.83	1.94
$b/MD	6	12.83	1.60
$b/Ha	21	139.05	22.74
Frequency	22	2.64	0.73
Tractor weeding			
MH/Ha	8	0.86	0.35
$b/MH	5	64.40	27.54
$b/Ha	5	51.00	12.45
Frequency	9	2.11	0.78
Pesticide and fertilizer application			
MD/Ha	4	1.22	0.33
$b/MD	3	17.00	1.73
$b/Ha (hand application)	6	37.33	31.51
MH/Ha	5	0.42	0.17
$b/MH	3	55.33	5.03
$b/Ha (tractor application)	7	19.29	5.35
minutes/Ha aerial spraying	2	1.10	0.14
$b/Ha	11	17.45	1.81
Frequency of hand applications	7	3.86	3.13
Frequency of tractor applications	11	4.09	2.47

Table 63. Continued

Operation	n	$\bar{X}$	S_x
Frequency of airplane applications	11	4.45	2.07
Frequency of all applications combined together	19	6.26	1.37
Harvesting			
lb/MD	3	158.33	38.19
$b/cwt (first hand)	15	13.13	1.30
lb/MD	2	140.00	14.14
$b/cwt (second hand)	16	15.50	2.83
lb/MD	3	73.33	37.86
$b/cwt (third hand)	12	17.17	2.29
Drying and handling			
MD/Ha	1	4.80	----
$b/Ha	2	119.00	82.27
Ginning			
$b/cwt (raw cotton)	11	35.00	0.00
Marketing			
lb/Ha ginned yield	22	12.85	5.25
$b/cwt transport	12	2.39	1.14
Salaries			
$b/month tractor driver	8	882.50	147.91
$b/month assistant	5	510.00	151.66
$b/month administrator	7	1,757.14	1,469.53
Land prices			
$b/Ha uncleared land	14	457.00	267.05
$b/Ha fallow land	6	483.00	271.42
$b/Ha mechanically cleared land	10	2,170.00	1,017.68

Table 64. Rice costs of production, per hectare

Operation	n	$\bar{X}$	S_x
Land preparation			
MD/Ha	1	12.00	----
$b/MD	1	11.00	----
MH/Ha	1	3.00	----
$b/Ha	5	196.40	77.88
Seeding			
MD/Ha	17	2.06	0.97
$b/MD	6	12.33	1.21
$b/Ha	37	54.46	14.56
lb/Ha seed	38	55.21	18.73
$b/cwt of seed	34	53.92	12.86
$b/Ha custom cost hand seeder	1	32.00	----
MH/Ha tractor seeding	1	1.00	----
First weeding			
MD/Ha	19	8.89	3.25
$b/MD	17	12.35	2.69
$b/Ha	39	109.62	29.00
Second weeding			
MD/Ha	9	8.11	2.85
$b/MD	8	12.25	2.25
$b/Ha	20	107.85	25.84
Insecticides and herbicides			
$b/Ha chemicals	3	42.17	25.18
$b/Ha application	3	22.33	6.35
Harvesting			
MD/Ha	12	38.50	12.34
$b/MD	9	12.89	3.22
$b/cwt	37	8.86	3.93
$b/Ha	38	482.39	155.44
Drying and handling			
MD/cwt	8	0.17	0.12
$b/MD	6	12.33	4.59
$b/cwt	35	1.70	0.93

Table 64. Continued

Operation	n	$\bar{X}$	S_x
Marketing			
$b/cwt transport to mill	33	2.13	0.91
cwt/Ha yield	38	51.92	19.37
$b/cwt price received	29	38.70	1.87
$b/cwt for milling	4	1.66	0.80
$b/cwt milled rice price	10	68.90	3.98
$b/cwt of rice for bags	16	0.72	0.57
$b/cwt fees to the union of growers	2	0.24	0.02
Land prices			
$b/Ha uncleared land	27	251.85	139.70
$b/Ha fallow land	27	216.67	132.60
$b/Ha hand cleared land	2	150.00	0.00

Table 65. Corn costs of production, per hectare

Operation	n	$\overline{X}$	S_x
Land preparation			
MD/Ha	6	15.33	8.24
$b/MD	6	12.67	1.37
$b/Ha (hand preparation)	14	175.07	61.63
MH/Ha	3	3.67	2.08
$b/MH	3	29.00	18.25
$b/Ha tractor plowing	3	96.67	55.08
MH/Ha	3	1.33	0.58
$b/MH	3	35.00	15.00
$b/Ha tractor levelling	3	41.67	7.64
Seeding			
lb/Ha seed	31	32.77	8.48
$b/cwt of seed	29	28.44	11.14
MD/Ha	24	3.25	1.85
$b/MD	19	13.42	3.15
$b/Ha (hand seeding)	32	51.25	21.81
First weeding			
MD/Ha	22	8.91	2.14
$b/MD	21	12.38	2.11
$b/Ha	31	115.48	26.53
Second weeding			
MD/Ha	10	7.90	2.42
$b/MD	9	13.11	2.71
$b/Ha	16	105.50	33.93
Harvesting			
MD/Ha	17	9.71	5.01
$b/MD	15	11.80	2.18
$b/Ha	26	141.00	67.84
$b/cwt	5	2.70	0.84
Shelling			
MD/cwt of grain	13	0.11	0.06
$b/cwt of grain	21	1.69	0.69
Handling and loading			
MD/cwt	2	0.16	0.15
$b/cwt	10	0.61	0.47

Table 65. Continued

Operation	n	$\bar{X}$	S_x
Marketing			
\$b/cwt transport to Santa Cruz	23	2.66	1.16
\$b/cwt bags (depreciation)	11	0.78	0.63
cwt/Ha grain yield	30	52.41	18.20
\$b/cwt price received	28	21.18	6.94
Land prices			
\$b/Ha uncleared land	14	260.71	137.53
\$b/Ha fallow land	12	316.67	250.76
\$b/Ha hand cleared land	1	2,000.00	----
\$b/Ha mechanically cleared land	2	1,100.00	565.69

Table 66. Yuca costs of production, per hectare

Operation	n	$\overline{X}$	S_x
Land preparation			
MD/Ha	6	13.00	4.00
$b/MD	6	14.00	2.00
$b/Ha	10	184.60	59.36
Seeding			
cwt/Ha seed	6	8.44	3.74
$b/cwt untreated seed price	2	4.94	2.45
MD/Ha seed treatment	9	1.77	1.38
$b/Ha seed treatment	12	50.33	29.14
MD/Ha	10	13.30	5.91
$b/MD	10	13.30	1.42
$b/Ha	17	153.65	76.68
First weeding			
MD/Ha	10	10.70	2.21
$b/MD	10	12.30	1.34
$b/Ha	15	122.67	20.52
Second weeding			
MD/Ha	9	9.78	0.67
$b/Ha	16	129.06	32.36
Third weeding			
MD/Ha	6	10.00	0.00
$b/Ha	8	112.50	23.75
Harvesting			
MD/Ha	8	32.50	15.81
$b/MD	7	12.43	3.05
$b/cwt	4	1.48	0.21
$b/Ha	8	372.50	178.15
Handling and loading			
MD/cwt	1	0.03	----
$b/cwt	6	0.40	0.20
Marketing			
cwt/Ha yield	15	359.33	212.59
$b/cwt transport to Santa Cruz	12	3.40	1.83
$b/cwt price received	10	11.98	3.52
Land prices			
$b/Ha uncleared land	10	215.00	133.44
$b/Ha fallow land	10	215.00	133.44

Table 67. Soybean costs of production, per hectare

Operation	n	$\bar{X}$	S_x
Land preparation			
MD/Ha	1	20.00	----
$b/MD	1	14.00	----
$b/Ha	3	176.67	92.92
Seeding			
MD/Ha	4	4.00	1.63
$b/MD	4	13.25	1.26
$b/Ha	6	54.50	17.16
lb/Ha seed	7	93.29	38.46
$b/cwt seed	6	67.17	17.34
First weeding			
MD/Ha	4	8.00	3.65
$b/MD	4	15.00	2.16
$b/Ha	7	113.71	29.90
Second weeding			
$b/Ha	3	113.33	11.55
Third weeding			
$b/Ha	3	113.33	11.55
Harvesting			
MD/Ha	4	12.50	5.00
$b/MD	4	13.75	1.50
$b/Ha	6	191.33	65.81
Threshing and handling			
MD/cwt threshing	1	0.33	----
$b/cwt threshing	4	3.40	0.95
$b/cwt handling	2	1.45	0.64
Marketing			
$b/cwt transport to Santa Cruz	5	4.00	2.92
cwt/Ha yield	7	26.17	7.30
$b/cwt price received	4	58.20	5.36
Land prices			
$b/Ha uncleared land	3	350.00	180.28
$b/Ha fallow land	2	275.00	176.78
$b/Ha hand cleared land	1	900.00	----

Table 68. Time distribution of the land clearing operations

Operation	Frequency of the observations Time period 1	2	3	4	5	6	Total $\bar{X}$	S_x^2
Mechanized land clearing								
Bulldozer tree clearing	0	1	1	2	0	1	3.80	2.20
Plowing	0	1	5	0	1	0	3.14	0.81
Levelling	0	0	3	0	1	0	3.50	1.00
Hand land clearing								
Brush clearing	0	2	5	5	0	0	3.25	0.57
Tree clearing	0	0	5	4	0	1	3.70	0.90
Burning and cleaning	1	2	1	18	26	1	4.53	0.71
Average[a]	1	0	7	32	13	1	4.20	0.58
Fallow land clearing								
Brush clearing	0	2	3	8	3	3	4.11	1.43
Burning and cleaning	0	1	3	6	8	1	4.26	0.98
Average[a]	1	0	2	6	4	0	4.38	1.09
Plowing land clearing								
Hand tree clearing	0	0	1	7	7	1	4.50	0.53
Plowing	0	0	0	2	4	4	5.20	0.62
Levelling	0	0	0	1	1	8	5.70	0.46

[a]Some of the interviewed farmers were not able to break down the time distribution for each single operation.

Table 69. Time distribution of the operations for sugar cane, wheat, and cotton

Operation	Frequency of the observations: Time period 1	2	3	4	5	6	Total: $\bar{X}$	S_x^2
Sugar cane								
Land preparation	0	0	9	12	4	2	3.96	0.81
Planting	0	1	2	14	52	6	4.88	0.46
First weeding	2	0	1	10	39	24	5.21	0.57
Second weeding	18	0	1	3	19	30	5.86	0.81
Third weeding	21	6	0	0	7	22	6.46	0.73
Harvesting	7	4	10	12	1	10	2.22	0.81
Wheat								
Land preparation[a]	0	0	2	0	0	0		
Seeding	0	1	10	0	0	0	2.91	0.09
First weeding[a]	0	0	0	3	0	0		
Second weeding[a]	0	0	0	0	1	0		
Spraying[a]	0	0	0	1	0	0		
Harvesting[a]	0	0	2	0	0	0		
Cotton								
Land preparation	0	0	0	2	7	7	5.31	0.50
Seeding	2	0	0	0	0	15	6.12	0.11
First hand weeding	13	0	0	0	0	6	6.68	0.23
Last hand weeding	7	10	0	0	0	1	1.50	0.38
First machine weeding	1	1	0	0	0	5	6.43	0.62
Last machine weeding	5	0	0	0	0	0	1.00	0.00
Harvesting	0	6	2	0	0	0	2.25	0.21

[a]No estimates were calculated for the mean ($\bar{X}$) and the variance (S_x^2) due to the small size of the sample

Table 70. Time distribution of the operations for rice, corn, yuca, and soybean

Operation	Frequency of the observations Time period 1	2	3	4	5	6	Total $\bar{X}$	S_x^2
Rice								
Land preparation	0	0	0	0	4	1	5.20	0.20
Seeding	0	0	0	0	15	23	5.61	0.25
First weeding	4	0	1	0	2	31	6.13	0.39
Second weeding	17	0	0	0	0	3	6.85	0.13
Harvesting	2	21	1	0	0	0	1.96	0.13
Drying and handling	0	13	11	0	0	0	2.46	0.26
Corn								
Land preparation	1	0	2	3	5	2	4.77	1.36
Seeding	3	1	2	2	15	9	5.38	1.15
First weeding	5	1	2	0	7	17	6.19	1.06
Second weeding	3	3	0	1	1	6	6.43	1.34
Shelling	3	2	3	2	0	1	2.18	1.76
Yuca								
Land preparation	0	0	5	3	2	0	3.70	0.68
Seeding	0	0	4	7	6	0	4.12	0.61
First weeding	0	0	1	6	4	5	4.81	0.96
Second weeding	4	2	0	2	5	3	5.94	1.66
Third weeding	1	1	0	1	1	3	6.00	1.67
Harvesting	1	2	2	4	0	1	2.70	2.01
Soybean								
Land preparation	1	1	1	0	0	0	2.00	1.00
Seeding	2	1	2	0	0	2	1.43	1.62
First weeding	0	2	2	1	0	1	2.33	1.87
Second weeding	1	1	0	1	0	0	2.33	2.33
Harvesting	0	1	0	1	0	0	3.00	2.00

Table 71. Daily wages to agricultural labor classified by time period

Time period	n	$\bar{X}_i$	S_x
1 January and February	31	12.84	1.81
2 March and April	37	12.27	2.10
3 May and June	36	13.33	2.83
4 July and August	55	13.33	1.90
5 September and October	56	13.39	1.82
6 November and December	71	12.70	1.94
Total	286		

Hypothesis: $\mu_1 = \mu_2 = \ . \ . \ . = \mu_6$

$\bar{X} = 13.00$ ($b/man-day)

Calculated value: $F = 2.16$; Tabulated value: $F_{(5,\ 280)\ .95} = 2.21$

The hypothesis is not rejected.

Table 72. Equality of means test for agricultural wages paid on all land clearing operations

Operation	n	$\bar{X}_i$	S_x
Hand clearing			
Brush clearing	11	13.18	2.40
Tree clearing	9	14.00	4.58
Burning and cleaning	32	12.50	1.66
Fallow land clearing			
Brush clearing	7	15.57	2.39
Burning and cleaning	11	13.45	2.01
Plow land clearing			
Hand tree clearing	5	14.40	2.51
Total	75		

Hypothesis: $\mu_1 = \mu_2 = \ . \ . \ . = \mu_6$

$\bar{X} = 13.33$

Calculated value: $F = 2.16$; Tabulated value: $F_{(5,\ 69).95} = 2.37$

The hypothesis is not rejected.

Table 73. Equality of means test for agricultural wages paid on sugar cane and cotton operations

Operation	n	$\bar{X}_i$	S_x
Sugar cane			
Land preparation	3	12.67	2.08
Planting	11	14.36	1.43
First weeding	21	14.00	1.73
Second weeding	18	13.50	2.31
Third weeding	10	13.00	2.40
Harvesting	8	15.62	2.87
Total	71		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_6$

$\bar{X} = 13.91$

Calculated value: F = 1.90; Tabulated value: $F_{(5,\ 66).95} = 2.37$

The hypothesis is not rejected

Operation	n	$\bar{X}_i$	S_x
Cotton			
Seeding	2	16.00	5.66
First weeding	6	12.83	1.60
Pesticide application	3	17.00	1.73
Total	11		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_6$

$\bar{X} = 14.55$

Calculated value: F = 3.14; Tabulated value: $F_{(2,\ 8).95} = 4.46$

The hypothesis is not rejected.

Table 74. Equality of means test for agricultural wages paid on rice and corn operations

Operation	n	$\bar{X}_i$	S_x
Rice			
Land preparation	1	11.00	----
Seeding	6	12.33	1.21
First weeding	17	12.35	2.69
Second weeding	8	12.25	2.25
Harvesting	9	12.89	3.22
Drying and handling	6	12.33	4.59
Total	47		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_6$

$\bar{X} = 12.40$

Calculated value: F = 0.1; Tabulated value: $F_{(5, 41).95} = 2.45$

The hypothesis is not rejected

Operation	n	$\bar{X}_i$	S_x
Corn			
Land preparation	6	12.67	1.37
Seeding	19	13.42	3.15
First weeding	21	12.38	2.11
Second weeding	9	13.11	2.71
Harvesting	15	11.80	2.18
Total	70		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_6$

$\bar{X} = 12.66$

Calculated value: F = 1.03; Tabulated value: $F_{(4, 65).95} = 2.53$

The hypothesis is not rejected.

Table 75. Equality of means test for agricultural wages paid on yuca and soybean operations

Operation	n	$\bar{X}_i$	S_x
Yuca			
Land preparation	6	14.00	2.00
Seeding	10	13.30	1.42
First weeding	10	12.30	1.34
Harvesting	7	12.43	3.05
Total	33		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_6$

$\bar{X} = 12.94$

Calculated value: F = 1.23; Tabulated value: $F_{(3, 29).95} = 2.92$

The hypothesis is not rejected

Operation	n	$\bar{X}_i$	S_x
Soybean			
Land preparation	1	14.00	----
Seeding	4	13.25	1.26
First weeding	4	15.00	2.16
Harvesting	4	13.75	1.50
Total	13		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_6$

$\bar{X} = 14.00$

Calculated value: F = 0.76; Tabulated value: $F_{(3, 9).95} = 3.86$

The hypothesis is not rejected.

Table 76. Equality of means test for agricultural wages paid on the different crops[a]

Operation	n_j	$\sum_{i=1}^{n_j} X_i$	$\sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2$	$\bar{X}_j$	$\lvert \bar{X}_j - \bar{X} \rvert$
Land clearing	75	1,000	496.67	13.33	0.14
Sugar cane	71	988	331.49	13.91	0.72
Wheat	5	60	0.00	12.00	1.19
Cotton	11	160	90.73	14.55	1.36
Rice	47	583	351.32	12.40	0.79
Corn	70	886	427.77	12.66	0.53
Yuca	33	427	123.88	12.94	0.25
Soybeans	13	182	32.00	14.00	0.81
Total	325	4,286	1,853.86		

$\bar{X} = \frac{4,286}{325} = 13.19;$ $\sum_{j=1}^{8} n_j(\bar{X}_j - \bar{X})^2 = 125.29$

Calculated value: $F = \frac{125.29}{1,853.86} \cdot \frac{317}{7} = 3.06$

Tabulated value: $F_{(7,\ 317).95} = 2.01$

The hypothesis is rejected

[a]All land clearing operations were taken as a whole to be compared with the different crops.

Table 77. Equality of means test for agricultural wages paid on the different crops arranged in two groups

Cotton, Soybean, and Sugar cane

$n = 95$

$\sum_{j=1}^{3} \sum_{i=1}^{n_j} X_{ij}^2 = 19,078$

$\sum_{j=1}^{3} \sum_{i=1}^{n_j} X_{ij} = 1,330$

$\sum_{j=1}^{3} \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2 = 454.22$

$\bar{X} = 14.00$

$\sum_{j=1}^{3} n_j (\bar{X}_j - \bar{X})^2 = 3.90$

$F = \frac{3.90}{454.22} \times \frac{92}{2} = 0.39 \quad F_{(2,\ 92).95} = 3.11$

The hypothesis of equality of means is not rejected.

Land clearing, Wheat, Rice, Corn, and Yuca

$n = 230$

$\sum_{j=1}^{3} \sum_{i=1}^{n_j} X_{ij}^2 = 39,424$

$\sum_{j=1}^{3} \sum_{i=1}^{n_j} X_{ij} = 2,956$

$\sum_{j=1}^{3} \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2 = 1,399.64$

$\bar{X} = 12.85$

$\sum_{j=1}^{3} n_j (\bar{X}_j - \bar{X})^2 = 33.20$

$F = \frac{33.20}{1,399.64} \times \frac{225}{4} = 1.33; \quad F_{(4,\ 225).95} = 2.37$

The hypothesis of equality of means is not rejected.

Table 78. Equality of means test for custom rates paid for tractor operation

Operation	n	$\bar{X}_i$	S_x
Mechanized land clearing			
Plowing	2	42.50	10.61
Levelling	4	96.25	49.90
Plow land clearing			
Plowing	5	98.20	31.66
Levelling	5	71.60	21.69
Wheat			
Seeding	2	41.00	8.49
Cotton			
Land preparation	6	90.83	40.90
Seeding	4	72.00	8.12
Weeding	5	64.40	27.54
Spraying	3	55.33	5.03
Corn			
Plowing	3	96.67	55.08
Levelling	3	41.67	7.64
Total	42		

Hypothesis: $\mu_1 = \mu_2 = \dots = \mu_{11}$

$\bar{X} = 74.83$ \$b per machine-hour

Calculated value: F = 1.68; Tabulated value: $F_{(10, 31).95} = 2.16$

The hypothesis is not rejected

Table 79. Equality of means test for land prices of uncleared land classified by provinces and crops, in $b per hectare

Province	n	$\bar{X}_i$	S_x
Santisteban	105	325.98	213.60
Sara	7	250.00	174.23
Warnes	9	475.00	244.24
Ibáñez	2	175.00	35.36
Ichilo	6	283.33	147.20
Total	129		

Hypothesis: $\mu_1 = \mu_2 = \ldots = \mu_5$

$\bar{X}$ = 325.80 $b per hectare

Calculated value: F = 1.66; Tabulated value: $F_{(4,\ 124).95} = 2.45$

The hypothesis is not rejected.

Crop	n	$\bar{X}_i$	S_x
Sugar cane	53	353.36	197.83
Wheat	8	406.25	376.49
Cotton	14	457.00	267.05
Rice	27	251.85	139.70
Corn	14	260.71	137.53
Yuca	10	215.00	133.44
Soybeans	3	350.00	180.28
Total	129		

Hypothesis: $\mu_1 = \mu_2 = \ldots = \mu_7$

$\bar{X}$ = 325.80 $b per hectare

Calculated value: F = 2.74; Tabulated value: $F_{(6,\ 122).95} = 2.18$

$F_{(6,\ 122).99} = 2.96$

The hypothesis is rejected at the 95 percent confidence level.

Table 80. Equality of means test for land prices of fallow land classified by provinces and crops, in \$b per hectare

	n	$\bar{X}_i$	S_x
Province			
Santisteban	79	290.19	205.78
Sara	7	407.14	324.59
Warnes	4	575.00	298.61
Ibáñez	-	----	----
Ichilo	5	240.00	151.66
Total	95		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_4$

$\bar{X}$ = 308.16 \$b per hectare

Calculated value: F = 2.84; Tabulated value: $F_{(3, 91).95} = 2.72$

$F_{(3, 91).99} = 3.95$

The hypothesis is rejected at the 95 percent confidence level

	n	$\bar{X}_i$	S_x
Crop			
Sugar cane	36	320.14	202.91
Wheat	8	475.00	373.21
Cotton	6	483.00	271.42
Rice	21	216.67	132.60
Corn	12	316.67	250.76
Yuca	10	215.00	133.44
Soybean	2	275.00	176.78
Total	95		

Hypothesis: $\mu_1 = \mu_2 = . . . = \mu_7$

$\bar{X}$ = 308.16 \$b per hectare

Calculated value: F = 2.47; Tabulated value: $F_{(6, 88).95} = 2.25$

$F_{(6, 88).99} = 3.12$

The hypothesis is rejected at the 95 percent confidence level

Table 81. Equality of means test for land prices of hand cleared land classified by provinces and crops, in $b per hectare

	n	$\bar{X}_i$	S_x
Province			
Santisteban	5	890.00	691.38
Sara	2	250.00	141.42
Warnes	2	600.00	424.26
Ibáñez	1	2,000.00	----
Total	10		

Hypothesis: $\mu_1 = \mu_2 = \mu_3 = \mu_4$

$\bar{X}$ = 815.00 $b per hectare

Calculated value: F = 1.90; Tabulated value: $F_{(3,\ 6).95} = 4.76$

The hypothesis is not rejected

	n	$\bar{X}_i$	S_x
Crop			
Sugar cane	6	825.00	629.09
Rice	2	150.00	0.00
Corn	1	2,000.00	----
Soybeans	1	900.00	----
Total	10		

Hypothesis: $\mu_1 = \mu_2 = \mu_3 = \mu_4$

$\bar{X}$ = 815.00 $b per hectare

Calculated value: F = 2.99; Tabulated value: $F_{(3,\ 6).95} = 4.76$

The hypothesis is not rejected

Table 82. Equality of means test for land prices of mechanically cleared land classified by provinces and crops, in $b per hectare

	n	$\bar{X}_i$	S_x
Province			
Santisteban	13	2,553.85	1,097.05
Sara	2	1,700.00	1,838.48
Warnes	6	2,833.33	2,228.60
Ibáñez	1	1,500.00	----
Total	22		

Hypothesis: $\mu_1 = \mu_2 = \mu_3 = \mu_4$

$\bar{X}$ = 2,504.54 $b per hectare

Calculated value: F = 0.46; Tabulated value: $F_{(3, 18).95} = 3.17$

The hypothesis is not rejected

	n	$\bar{X}_i$	S_x
Crop			
Sugar cane	6	2,700.00	894.43
Wheat	4	3,750.00	2,217.36
Cotton	10	2,170.00	1,017.68
Corn	2	1,100.00	565.69
Total	22		

Hypothesis: $\mu_1 = \mu_2 = \mu_3 = \mu_4$

$\bar{X}$ = 2,504.54 $b per hectare

Calculated value: F = 2.43; Tabulated value: $F_{(3, 18).95} = 3.17$

The hypothesis is not rejected

Table 83. Equality of means test for land prices of uncleared and fallow land, in $b per hectare

	n	$\bar{X}_i$	S_x
Uncleared land	129	325.80	209.09
Fallow land	95	308.16	223.53
Total	224		

Hypothesis: $\mu_1 = \mu_2$

$\bar{X}$ = 318.32 $b per hectare

Calculated value: F = 0.37; Tabulated value: $F_{(1, 222).95} = 3.84$

The hypothesis is not rejected

Table 84. Average estimated land prices in $b per hectare

Land type	Average price
Uncleared land & fallow land	318.32
Hand cleared land	815.00
Mechanically cleared land	2,504.54

Value added by hand clearing the land	815.00 - 318.32 = 496.68
Value added by mechanically clearing the land	2,504.54 - 318.32 = 2,186.22

Appendix B

Time Distribution of the Operations

The year was arbitrarily divided into six periods of two months each. The computer tabulation of the questionnaires showed the number of farmers interviewed in the sample that carried out each operation for each crop in each of the time periods.

It was assumed that the proportion of the farmers that carry out an operation is distributed over time following a normal distribution function. The mean value (μ) and standard deviation (σ_x) of the universe of all farmers were estimated by the mean ($\bar{X}$) and standard deviation (S_x) of the sample. These two parameters were calculated for each operation. A difficulty was encountered in the calculation of $\bar{X}$ and S_x because their values differ if the sequence of time periods is moved along the time axis. This will be better explained by means of an example. Let's assume that the number of farmers in the sample, planting cotton in each period are the following:

Period	Jan.&Feb.	Mar.&April	May&June	July&Aug.	Sep.&Oct.	Nov.&Dec.
f	20	10	0	0	10	20

If the time periods are given X values of 1,2,3,4,5, and 6 respectively,

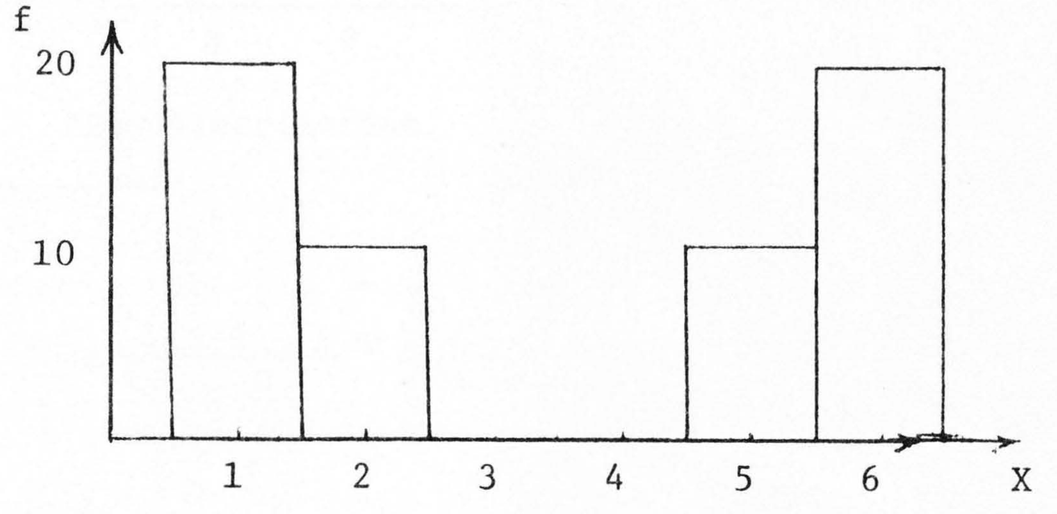

Figure 13. Time distribution.

(Figure 13) the calculated values will show amean value $\bar{X} = 3.5$ and a variance $S^2 = 5.09$.[62]

The interpretation of the data assumed in these numbers is that half of the farmers do this operation at the beginning of the year while the rest wait until the end of the year, the sample representing a universe of farmers that tend to plant cotton in higher proportion in the middle of the year ($\bar{X} = 3.5$), but not significantly higher than the rest of the year since the time frequency is widely distributed ($S_X^2 = 5.09$). This could clearly not be the case, especially in tropical climate where all farmers are compelled by climatic conditions to procede with certain operations at approximately the same time. The "right" interpretation would, therefore, be that half the farmers start planting cotton by the end of the year while the other half do it immediately after, that is, at the beginning of the new calendar year. The correct procedure would be to assign the different time periods a series of values such as X = 4,5,6,1,2, and 3 with the results: $\bar{X} = 3.5$; $S_X^2 = .93$, as illustrated in Figure 14. These parameters

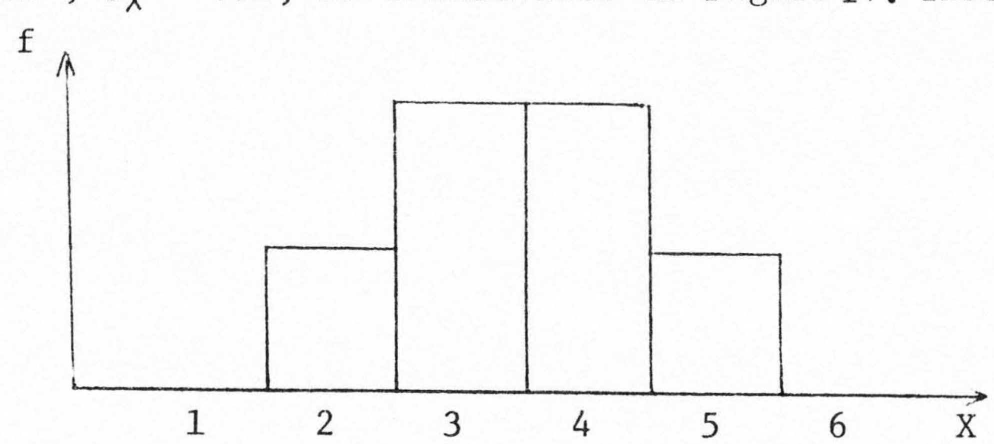

Figure 14. Time distribution

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[62] Where:

$$X = \frac{\sum_{x-1}^{6} f\,x}{N} \; ; \quad S_X^2 = \frac{\sum_{x-1}^{6} f\,(x - \bar{X})^2}{N - 2} \; ; \quad N = \sum_{x=1}^{6} f$$

provide a normal distribution function that approaches the time distribution of the tabulated values of the sample.

Calculations were made for each operation in each crop, assigning th six different possible time sequences (1,2,3,4,5,6; 6,1,2,3,4,5; 5,6,1,2, 3,4; 4,5,6,1,2,3; 3,4,5,6,1,2; 2,3,4,5,6,1). To avoid the introduction of any possible personal biases here, that sequence showing the smallest variance was selected and the corresponding value of the mean was calculated. The results appear in Table 85. Wheat and woybeans were not included in the table because the number of observations was so small that results were unreliable.

Once the mean and the standard deviation had been estimated, the next step was to find in the tables the proportion of members of the universe of farmers considered that would be expected to fall within each time interval. Certain operations that had a "high" standard deviation were assumed to be homogeneously distributed throughout the year. The wheat and soybean distributions were roughly approximated, based on the field observations of the author.

Table 85. Mean value and standard deviation of the frequency distributions for each operation[a]

Operation	$\bar{X}$	S_x
Mechanized land clearing		
Bulldozer tree clearing	3.80	1.48[b]
Plowing	3.14	0.90[b]
Levelling	3.50	1.00[b]
Hand land clearing		
Brush clearing	3.25	0.75
Tree clearing	3.70	0.95
Burning and cleaning	4.53	0.84
Fallow land clearing		
Brush clearing	4.11	1.20
Burning and cleaning	4.26	0.99
Plowing land clearing		
Hand tree clearing	4.50	0.73
Plowing	5.20	0.79
Sugar cane		
Land preparation	3.96	0.90
Planting	4.88	0.68
First weeding	5.21	0.75
Second weeding	5.86	0.90
Third weeding	6.46	0.85
Harvesting	2.22	0.90
Cotton		
Land preparation	5.31	0.71
Seeding	6.12	0.33
First hand weeding	6.68	0.48
Last hand weeding	1.50	0.62
First machine spraying	6.43	0.79
Last machine spraying	1.00	0.62
Harvesting	2.25	0.46
Rice		
Land preparation	5.20	0.45
Seeding	5.61	0.50
First weeding	6.13	0.62
Second weeding	6.85	0.36
Harvesting	1.96	0.36
Drying and handling	2.46	0.51
Yuca		
Land preparation	3.70	0.82
Seeding	4.12	0.78

Table 85. Continued

Operation	$\overline{X}$	S_x
First weeding	4.81	0.98[b]
Second weeding	5.94	1.29[b]
Third weeding	6.00	1.29[b]
Harvesting	----[c]	1.42[b]
Corn		
Land preparation	4.77	1.17[b]
Seeding	5.38	1.07[b]
First weeding	6.19	1.03[b]
Second weeding	6.43	1.16[b]
Shelling	2.18	1.33[b]

[a]Here, X = 1 refers to January and February; X = 2 to March and April, etc.

[b]The high value of the standard deviation gives reason to believe that the operation is evenly spread over the entire year. Wheat and soybean are not included because of the small number of observations.

[c]Two different values of $\overline{X}$ were obtained with the same value of S_x

Table 86. Percent that is expected to carry out each operation in each crop at each time period

Operation	Time period 1	2	3	4	5	6
Wheat						
Land preparation	30	50	20	0	0	0
Seeding	0	40	60	0	0	0
Spraying	0	30	50	20	0	0
Harvesting	0	0	0	70	30	0
Corn						
Land preparation	0	0	0	30	50	20
Seeding	11	0	0	0	56	33
First weeding	17	0	0	0	24	59
Second weeding	25	25	0	0	0	50
Harvesting	50	25	25	0	0	0
Shelling	17	17	17	17	16	16
Yuca						
Land preparation	2	9	48	23	14	4
Seeding	1	4	21	44	24	6
First weeding	16	16	17	17	17	17
Second weeding	17	16	16	17	17	17
Third weeding	17	16	16	17	17	17
Harvesting	17	17	17	17	16	16
Winter soybeans						
Land preparation	30	50	20	0	0	0
Seeding	0	40	60	0	0	0
First weeding	0	30	50	20	0	0
Second weeding	0	20	50	30	0	0
Third weeding	0	20	40	40	0	0
Spraying	0	20	50	30	0	0
Harvesting	0	0	0	70	30	0
Threshing and handling	0	0	0	70	30	0
Mechanized land clearing						
Bulldozer tree clearing	16	16	17	17	17	17
Plowing	16	16	17	17	17	17
Levelling	16	16	17	17	17	17
Hand land clearing						
Brush clearing	3	15	44	30	7	1
Tree clearing	3	10	31	36	15	5
Burning and cleaning	3	3	10	36	36	12
Fallow land clearing						
Brush clearing	4	8	21	33	24	10
Burning and cleaning	2	5	17	38	27	11

Table 86. Continued

Operation	Time period 1	2	3	4	5	6
Plowing land clearing						
Hand tree clearing	2	2	9	39	39	9
Plowing	3	1	5	27	47	17
Sugar cane						
Land preparation	2	6	24	40	22	6
Planting	3	1	5	24	50	17
First weeding	6	1	3	16	45	29
Second weeding	19	5	2	7	26	41
Third weeding	34	11	3	3	12	37
Harvesting	21	41	24	6	2	6
Cotton						
Land preparation	0	0	2	13	69	16
Seeding	1	0	0	7	77	15
First hand weeding	1	1	1	3	32	62
Last hand weeding	41	41	7	2	2	7
First machine spraying	34	10	2	3	11	40
Last machine spraying	55	19	3	1	3	19
Harvesting	8	60	28	3	0	1
Plowing	6	49	36	9	0	0
Rice						
Land preparation	2	0	1	9	63	25
Seeding	6	0	0	4	38	52
First weeding	24	4	1	2	15	54
Second weeding	73	6	1	0	1	19
Harvesting	14	77	9	0	0	0
Drying and handling	6	46	41	5	1	1
Summer soybean						
Land preparation	0	0	0	30	50	20
Seeding	0	0	0	0	60	40
First weeding	20	0	0	0	30	50
Second weeding	30	0	0	0	20	50
Third weeding	40	0	0	0	20	40
Spraying	30	0	0	0	20	50
Harvesting	70	30	0	0	0	0
Threshing and handling	70	30	0	0	0	0

Appendix C

Sugar Cane Transport Costs

Table 87. Distribution of 54 sugar cane producing areas by province and processing mill

Producer area number	Area name	Province	Mill site[a]	Amount delivered MT	Cost $b
2	Aroma	1	2	46,349	1,158,725
3	Cuatro Ojitos	1	1	140,998	3,242,954
4	Caimanes	1	1	27,081	649,944
7	Mineros	1	1	111,433	2,340,093
8	Chané	1	3	103,143	3,713,148
11	Illimani	1	1	6,418	154,032
12	Los Amarillos	1	1	21,439	493,097
15	San Félix	1	1	13,561	216,976
20	Naico	1	3	29,846	775,996
20	Naico	1	2	59,529	1,428,696
21	La Loma	1	2	38,570	887,110
22	San Pedro	1	2	14,620	526,320
24	Saavedra	1	1	66,635	1,066,160
25	Guabirá	1	2	63,360	1,457,280
26	San Salvador	1	1	6,713	140,973
32	Santa Teresa	1	3	340	9,180
43	Naranjito	1	2	1,730	36,330
48	El Naranjal	1	3	20,560	514,000
53	Pico de Monte	1	1	14,480	304,080
	Total			786,805	19,115,094
1	California	2	3	19,722	670,548
5	Portachuelo	2	2	35,595	889,875
34	Santa Rosa	2	1	790	18,170
37	San Juan	2	3	7,545	226,350
	Total			63,652	1,804,943
9	Candelaria	3	3	27,212	653,088
10	Los Ciervos	3	2	6,490	149,270
13	Los Chacos	3	2	57,849	1,504,074
14	Chuchio	3	3	26,802	616,446
16	Azusaquí	3	2	78,180	1,641,780
23	Warnes	3	3	48,260	1,109,980

Table 87. Continued

Producer area number	Area name	Province	Mill site[a]	Amount delivered MT	Cost $b
28	Tocomechi	3	3	12,760	306,240
33	Santa Rosario	3	3	692	16,608
35	Santa Martha	3	1	7,908	181,884
40	San Antonio	3	3	2,654	61,042
41	Okinawa	3	3	7,740	208,980
45	Monte Verde	3	2	1,540	46,200
46	Monte Cristo	3	2	7,310	153,510
47	Las Muñecas	3	1	2,240	53,760
49	Juan Latino	3	2	21,430	342,880
	Total			309,067	7,045,742
17	La Bélgica	4	2	35,950	431,400
18	La Guardia	4	3	12,970	272,370
19	Palmar Viruez	4	3	21,000	336,000
27	Terebinto	4	3	8,597	197,731
29	La Angostura	4	3	336	8,736
30	Villa Arrién	4	3	3,080	64,680
31	Tarumaco	4	3	15,590	358,570
39	San Aurelio	4	3	6,930	83,160
42	Paurito	4	3	7,545	120,720
44	Montero Hoyo	4	3	10,100	242,400
50	Cotoca	4	3	4,690	98,490
	Total			126,788	2,214,257
6	Yapacaní	5	2	66,238	2,384,568
36	San Miguel	5	1	4,280	89,880
38	San Carlos	5	1	4,734	118,350
38	San Carlos	5	3	3,086	111,096
51	Buena Vista	5	1	7,250	174,000
52	Colpa	5	2	4,260	68,160
54	Buen Retiro	5	1	9,240	240,240
	Total			99,088	3,186,294
	Grand total			1,385,400	33,366,330

Source: Wennergren, Boyd, et.al. Irrigation and Non-irrigation Alternatives for Reducing Sugar Cane Transportation Costs in Santa Cruz, Bolivia, Utah State University, Department of Economics, Cususwash, June 1973. pp. 22-23.

[a]The symbols are: Guabirá 1; La Bélgica 2; San Aurelio 3.

Table 88. Average transport costs for sugar cane, to the mills, per province, in $b per metric ton

Province	Transport cost $b/MT
Santisteban	24.29
Sara	28.36
Warnes	22.80
Ibáñez	17.46
Ichilo	32.16

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