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JOHNSTON, Tim David, 1942-
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Income potential of small farms

in Guatemala

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Tim David Johnston

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CHAPTER I. INTRODUCTION

Like many other developing countries, Guatemala provides a good example of economic and cultural dualism. The Guatemalan economy consists of a dynamic and growing modern commercial sector which exists side by side with a large subsistence sector. Most of the development work in Guatemala, as in most developing countries, has been concentrated on the modern sector. Agricultural development efforts to date have created large prosperous, commercial farms which produce coffee, cotton, sugar cane, and more recently beef for export markets. Guatemalan industries produce: sausages, milk products, jams and jellies, canned fruits and vegetables, animal feeds, breads, candies, vegetable oils, margarines, instant coffee, ice creams, alcoholic beverages, cigarettes, textiles, shoes, furniture, paper products, tires, innertubes, fertilizers, chemicals, glass, cement, and bicycles, to name only a few of the many products mentioned in the 1965 Industrial Census. These products are sold locally as well as within the Central American Common Market. Some products are sold to countries outside the Common Market, and these sales will probably increase. As the above list of products suggests, there has been a considerable development effort directed toward this modern sector. The modern aspect of Guatemala City, the network of all-weather roads, the existence of modern hotels and offices, and a modern airport all attest to the fact that Guatemala's modern agricultural, industrial, and service subsectors are developing. Over the past fifteen years, Guatemalan GNP has been growing at about 4.5-5% a year. Virtually all of this growth has taken place in the modern sector. The traditional sector has been stagnating during this period, and the position of the small traditional farmer has deteriorated considerably since the 1950's.

The Problem and the Setting

The stagnation of the traditional sector and the growth of the modern sector presents a pattern which is quite familiar to students of underdevelopment. Most development efforts have concerned themselves with promotion of industrialization within the modern sector. Indeed, in this respect Guatemala has been one of the more successful of the developing countries. This success, however, has also caused some problems, because a majority of Guatemala's population still lives in the traditional sector. It has been estimated that as of 1964, two-thirds of the total population lived in rural areas and 55% of these people lived in the nine highland departments comprising the area commonly called the western highlands (Merrill, 1974). Thus, there is a decidedly regional cast to the cultural and economic dualism which has been intensified by the industrialization process. While part of the country is growing and developing, the rural areas and particularly rural areas in the western highlands are stagnating. This situation presents the country with three serious problems.

First, the stagnation of the traditional sector represents a drag on the growth of the overall economy and contributes to the inequality of the income distribution. Second, the standard of living experienced by the traditional farmer is a source of political discontent which, if not alleviated, might lead to problems of political instability. Third, and perhaps most important, the combination of low living standards, shortages of arable land and rising population has created quite high man/land ratios in the western highlands. In many cases this has resulted in out migration, usually to a regional capital, Guatemala City or to the south coast. These migrants are for the most part unskilled (many are illiterate). The cities, particularly Guatemala City, have not been able to absorb all of them. This has caused unemployment which often leads to increasing crime rates which are another source of discontent that could contribute to political instability. Those migrants who go to the south coast find that there is little unoccupied land. They may find employment on large fincas as laborers or sharecroppers, but the capacity of the fincas to absorb more of this migrant labor is being strained. Large landowners would prefer that this migration be halted because large estates in close proximity with landless peasants have frequently resulted in land reforms.

In short, the problem is simply that people in the traditional sector have been unable to earn satisfactory incomes and as a result have begun to migrate out of the western highlands. The Government would like to redirect and preferably slow or stop this migration. To this end, the Government has embarked upon the present Rural Development Plan. There are three distinct programs in the plan: (1) the Basic Grains Program featuring both agricultural credit and technical assistance components; (2) an Agricultural Diversification Program; and (3) Stimulation of Handicrafts and Cottage Industries Program. Only the first and second programs have been initiated and greatest progress has been made on the Basic Grains Program. The goals of the Basic Grains Program are to: (1) increase the production of corn, beans, wheat, rice, and sorghum; (2) raise the level of incomes experienced by the small and medium sized farmer (one target level often mentioned is Q1,000 per family by 1980); (3) increase employment in traditional agriculture; and (4) introduce the small farmer to new agricultural technologies which will be complementary with the three goals mentioned above. Given an inelastic demand for basic grains, goals (1) and (4) are not complementary with goal (2). It was for this reason that the Agricultural Diversification Program was conceived. The rationale is that as new agricultural technologies are adopted, production per hectare will increase so that land presently occupied in production of basic grains will be freed for production of other crops--principally fruits and vegetables.

Eventually, the Stimulation of Handicrafts and Cottage Industries Program is to be implemented, but at present this phase is still in the initial planning stages. Some people have questioned the need for this program and there is hope in some quarters that the Basic Grains Program by itself will be capable of achieving substantial gains in employment and income for small farmers in the western highlands.

Objectives of This Research

The general objective of this study is to model a small farm in order to estimate how different farm sizes, availability of agricultural credit, adoption of new technologies, and availability of off-farm employment will affect the small farmer's income and employment. The model can be used to identify which resources effectively limit the farmer's decisions and to illustrate where policymakers could assist in the elimination of production bottlenecks. It can also be used to identify the monetary value of resources which are in short supply; and perhaps most important, the model can be used to estimate the income earning and employment generating effect of the current Basic Grains Program for individual farmers.

The analysis which is presented here is, of course, only capable of providing estimates. The reliability of these estimates will depend primarily on the validity of several key assumptions, one of which is that the Basic Grains Program will successfully reach traditional farmers. Other key assumptions relate to the input and output prices specified in the analysis, and will be discussed further in Chapter III.

Perhaps the most significant contribution of the present analysis is that it provides estimates not only of the income and employment levels which participating farmers might achieve but also of the goals which policymakers have set for the Basic Grains Program. Will the Basic Grains Program be capable of achieving a family income of Q1,000 per year? How much land would the family need to achieve this income level? Will small farmers continue to seek migratory employment on the cotton and coffee fincas if they become participants in the program?

While the linear programming model cannot definitely answer all of these questions, it does shed some light on them. This type of information should help policymakers understand the probable effects of their programs and to determine whether or not these programs are capable of achieving the established policy goals. If current programs cannot do this, then policymakers must begin to plan additional programs capable of achieving present goals; or they must revise these goals by reassessing the priority rankings which led to their adoption.

There are several reasons for estimating the effect of the Basic Grains Program at the individual farm level rather than at the regional or national levels. First, this is the level at which the program is directed, and the ultimate success or failure of the program will be determined at the individual farm level. Second, regional and national data on soil types is somewhat sketchy. Simmons prepared a soil reconnaissance survey (Simmons *et al.*, 1958) which is quite good, but it is not (and was not intended to be) a highly detailed soil survey. The lack of detailed information on soil types is relatively more serious for a regional or national study, although it hampers analysis at all levels. Third, information on yields for different soil types is completely unavailable at the national or regional levels. This study has been able to draw upon sample data (Johnston, 1973a) which relates yield to slope and hence indirectly to soil type on a small number of highland farms. Fourth, information on the percentage of the agricultural labor force which uses different agricultural technologies is largely unavailable. This makes it very difficult to effectively estimate regional production of basic grains. Furthermore, information on the rural population and rural labor force is somewhat unreliable because of the difficulty of discriminating the traditional agricultural labor force from modern farmers and nonagricultural labor in rural areas. For these reasons and others it was decided to restrict the analysis to the farm level.

Method of Analysis

The method of analysis which was deemed most appropriate for this study was linear programming. Chapter III explains the reasons for this choice and describes some of the more important characteristics of the model. Most of the analysis is done by varying different combinations of resources such as land, labor, knowledge and labor sales opportunities.

The weights and measures used in the analysis are primarily those in use in Guatemala. The land unit used here is the hectare which is approximately equal to 2.47 acres. Unless otherwise specified, yields are measured in quintales (qq) which is Spanish for hundredweight (cwt). Temperatures are given in degrees centigrade and rainfall is measured in millimeters (mm). The monetary unit is always the Quetzal (Q) which equals one U.S. dollar. A table containing units of measure used in the study is included in Appendix C.

Organization of the Study

Chapter II describes the geography, climate, population and some general cultural characteristics of the study area. Chapter III contains a description of the model and a brief presentation of the activities and the data. Chapter IV expands the discussion of the activities and data in order to provide perspective on the technologies and yield levels included in the analysis. Chapter V describes the experimental design and presents the results of the optimal solutions. The analysis begins with a traditional farmer who has limited amounts of savings, no credit availability, only one hectare of land and produces traditional crops with traditional technology. Through successive solutions he is given credit, land, and acquires knowledge of other technologies and crops through participation in the Basic Grains Program. His crops, income, employment, and other variables are noted and compared as his resource set is expanded. Chapter VI discusses the ability of the model to reproduce the position of the small farmer and then discusses and compares the results presented in Chapter V. Chapter VII provides a summary of the results, and makes suggestions for further research.

CHAPTER II. THE STUDY AREA

The present analysis is directed at the farm level, and, consequently, it may seem inappropriate to speak of any area larger than a farm. The farm studied, however, is meant to be representative of a type of agriculture carried out in a particular region, the western highlands. It is for this reason that information pertaining to the study area is of interest.

The western highlands, as a region, is not clearly defined. There are at least four separate regionalization schemes commonly used to identify the area. Each of these regionalization schemes has commendable or desirable aspects, and each is appropriate for its purpose. This study uses the regionalization scheme used by Merrill (1974) which defines the western highlands as an area falling within the boundaries of nine highland departments. This definition allows the use of departmental census data which is readily available for the region. It has the disadvantage of including areas which are not strictly "highlands" because political divisions include some lowland areas of the south coast as well as some lowland areas which are geographically a part of the Petén. More precisely, one could define the study area as the highland or mountainous region which centers around the Department of Totonicapán and includes parts of Quezaltenango, San Marcos, Huehuetenango, Quiché, Chimaltenango, Sololá, Baja Verapaz, and Alta Verapaz.

Depending upon the exact set of departments and municipios which one would decide to include as truly "highland" areas, the total land area covered by this region would vary from about 9,800 to 37,431 square kilometers. This would amount to between 9 and 34% of the total land area in Guatemala depending on how restrictively one wishes to define the region.

Population

Population in this region can be characterized as being largely rural and Indian. The 1964 census data in Table 2.1 gives a breakdown on rural and Indian population by department. Population in the western highlands was 83.5% rural and 72.1% Indian in 1964. In the rest of the country, population was only 55.5% rural and only 18.0% Indian. For the country as a whole 65.9% of the population was rural and 42.2% was Indian. These figures highlight the fact that the western highlands is distinct culturally as well as climatically.

Another important characteristic of this area is that population is growing. This growth has taken place in spite of the fact that man/land ratios are already quite high. Population growth rates by department and for the highlands and the country as a whole based upon changes in population between 1950 and 1964 are presented in Table 2.2. Highland population grew at the rate of 2.5% per year over this fourteen-year period.

This growth rate if unchecked could have serious, possibly

Table 2.1. Rural and Indian populations in the western highlands, 1964[a]

Department	Total population 1964	Rural population	Rural as % total	Indian population	Indian as % total
	(1,000 persons)				
Chimaltenango	163	101	62.3	122	74.6
Sololá	108	70	65.3	101	93.7
Totonicapan	142	121	85.5	135	95.1
Quezaltenango	271	173	64.1	149	55.1
San Marcos	337	295	87.7	169	50.2
Huehuetenango	288	241	83.8	200	69.3
Quiché	250	217	86.9	212	84.8
Baja Verapaz	96	81	84.0	54	55.5
Alta Verapaz	260	231	88.7	241	92.4
Highland sub-total	1915	1531	83.5	1382	72.1
Other departments	2373	1294	55.5	427	18.0
Republic	4288	2825	65.9	1809	42.2

Source: VII Censo de Población, 1964.

[a]Merrill, 1974, p. 7.

Table 2.2. Population of the western highlands, 1950 and 1964[a]

Department	Total population in 1,000's		Average annual growth rate (%)
	1950	1964	
Chimaltenango	121	163	2.2
Sololá	83	108	2.0
Totonicapan	99	142	2.6
Quezaltenango	184	271	2.8
San Marcos	233	337	2.7
Huehuetenango	200	288	2.6
Quiché	175	250	2.6
Baja Verapaz	66	96	2.7
Alta Verapaz	190	260	2.3
Highland sub-total	1351	1951	2.5
Other departments	1440	2373	3.6
Republic	2791	4288	3.1

Source: Ministerio de Economia, Dirección General de Estadistica;
1. VI Censo de Población, 1950.
2. VII Censo de Población, 1964.

[a]Merrill, 1974, p. 2.

disastrous, consequences. There simply is not enough good land to support a population growth rate of this magnitude. Census data shows that farm size shrank from 8.1 to 6.2 ha between 1950 and 1964. Merrill's estimates, presented in Table 2.3, show that both average farm size and farm land per person will decrease drastically if the indicated trends continue. If present growth in population remains unchecked, the amount of farm land available per person by the year 2000 will be only 0.42 ha. Furthermore, this will not be 0.42 ha of good land but would also contain poor land as well as some unarable land. Soil scientists agree that some of the land presently being farmed in the highlands should be classified as unarable and is suited only for pasture and forest use. An idea of how much of the projected 0.42 ha per person would be good land is provided by Table 2.4 which presents percentages of good, poor, and not arable land in each department. These percentages are based upon the soil reconnaissance work done by Simmons et al., in 1958. For purposes of argument, let us assume that land in farms would consist only of good and poor land in terms of this classification. If this is the case, then within the 74.2% of all land in these nine departments which can be considered highland (as opposed to coastal or tropical land) 37.6% of this land is not arable and, hence, is assumed to not be included as part of the total land area in farms. Of the remaining 62.4%, 23.8% is good land and 76.2% is poor land. Thus, even under a favorable assumption regarding quality of land area in farms, only 23.8% of the projected 0.42 ha per capita

Table 2.3. Projected farm size in western highlands, 1970-2000[a]

Year	Nine highland departments: Number of farms 1) (1,000)	Average farm size 2) (ha)	Farm land per person in rural population 3) (ha/person)
Census			
1950	203	8.1	1.35
1964	256	6.2	1.03
Projections			
1970	279	5.6	0.89
1975	298	5.3	0.78
1980	317	5.0	0.69
1990	355	4.5	0.54
2000	292	4.0	0.42

Notes: 1) Projected number of farms based on the average annual increase in the number of farms between 1950 and 1964.

2) Projections based on the assumption that total land in farms remains equal to the 1964 value of 1,581,600 hectares.

3) Projections based on the assumptions that population will increase at the 1950-1964 rates and total land area in farms remains constant at 1,581,600 hectares. Highland departments are: Chimaltenango, Sololá, Totonicapan, Quezaltenango, San Marcos, Huehuetenango, Quiché, Baja Verapaz, and Alta Verapaz.

[a]Merrill, 1974, p. 23.

Table 2.4. Land classifications for the western highland departments (percent of total land area)[a]

Department	Highland land types			
	1[b] Good	2[c] Poor	3[d] Not arable	Total highland
Chimaltenango	18.6	39.0	6.3	63.9
Sololá	1.0	61.6	19.4	82.0
Totonicapan	5.5	80.4	14.1	100.0
Quezaltenango	6.0	27.8	8.2	42.0
San Marcos	1.6	43.2	19.2	64.0
Huehuetenango	19.0	33.0	45.9	98.0
Quiché	9.4	16.0	55.8	81.2
Baja Verapaz	17.1	55.9	26.2	99.2
Alta Verapaz	9.0	37.1	2.1	48.2
Total[e]	11.0	35.3	27.9	74.2

[a]Merrill, 1974, p. 20.

[b]Good agricultural land. Includes much of the land area presently farmed intensively in many departments. Much of this land is relatively flat or moderately sloped and frequently located in highland valleys.

[c]Poor agricultural land. The land at high altitudes is not particularly well suited for pasture and/or forest. Some scattered areas are suited for potatoes and wheat and, to a much lesser extent, corn although frost is a continual risk.

[d]Not arable. Most of this land is steeply sloped and highly eroded or will erode rapidly if farmed.

[e]Totals are weighted averages.

Coastal land types		Tropical land types	
4 Good	5 Poor	6 Good	7 Poor
5.9	30.2	--	--
--	18.0	--	--
--	--	--	--
36.1	21.9	--	--
14.7	21.3	--	--
--	--	--	2.0
--	--	17.7	1.1
--	--	--	0.8
--	--	10.8	41.0
3.7	5.4	6.5	10.2

would be good land. This means that a family of four in the year 2000 would have a farm composed of 1.68 ha Of this 1.68 ha, only 0.40 ha would be good land and 1.28 ha would be poor land. The implications of this resource base for family income will be discussed in Chapter VI.

Geography

The western highlands is an area of great geographic and climatic diversity. Much of the region consists of very rough terrain in which one finds small areas that might be described as sub-tropical. These spots exist in contrast with the general climate of the region which is best described as being a low mountain climate and which, in some ways, is quite similar to a mild temperate climate.

There are two major mountain ranges in the western highlands, the Sierra Madre and the Cuchumatanes Mountains. Geologically these are distinct ranges, and may be differentiated by their characteristic soil groupings. There are also some climatic differences between them. The average altitude of the region ranges from about 2,100 to 2,700 msnm (meters above sea level).

Sierra Madre

The Sierra Madre is centered around the Departments of Totonicapan, Quezaltenango and Sololá. It extends down from Mexico to El Salvador and Honduras like the backbone of Central America. Many of the soils in the Sierra Madre are of volcanic origin and there are still more than 30 active volcanoes along the southern edge of the Sierra Madre, some of which rise to altitudes of 4,000 msnm and higher (Dombrowski et al., 1970, p. 44).

Earthquakes, which are due to volcanic activity as well as to the movements of faults which lie off the southern coast, are common in this area. Today as in the past, earthquakes are a potentially dangerous and destructive force. Although there have been no major earthquakes in Guatemala since 1918 when a series of earthquakes did substantial damage to Guatemala City, tremors and volcanic eruptions are fairly common. These tremors do little damage, because most buildings constructed since 1918 have enough flexibility to resist all but the most severe quakes.

The topography of the Sierra Madre is characterized by volcanic peaks, deep gorges, some valleys, and steep ridges. Much of the land is rolling but more is "quebrado" or very steep. The gorges and ravines which have been cut through the volcanic soils by short, abruptly falling rivers impede transportation. Most rivers coming out of the Sierra Madre flow into the Pacific Ocean. They are navigable for only very short distances in small boats. These rivers currently provide much of Guatemala's electric power.

Two important lakes in this area are Lake Atitlán in the Department of Sololá and Lake Amatitlan in the Department of Guatemala. Lake Atitlán is considered to be one of the most beautiful lakes in the world.

Sierra de los Cuchumatanes

The Cuchumatanes mountain range enters Guatemala from Mexico. It is essentially a massif of dolomite and limestone in sharp contact with granite, and is located principally in the Departments of Huehuetenango and Quiché. The high plateau of the Cuchumatanes Mountains is approximately 3,300 msnm. This is a relatively dry and unfertile area in which sheep grazing is one of the more important economic activities. Some potatoes and habas (broad beans) are grown. Corn and wheat are generally not grown, because most varieties do not respond well to the dryness, high altitude, and shorter growing season characteristic of the plateau.

The terrain in the Cuchumatanes Mountains is very rugged and presents a deeply dissected surface which restricts transportation as well as agricultural exploitation in most of the area. Agriculture is usually located in small pockets of good land tucked here and there about the landscape and along the flood plains of fertile river valleys. The ruggedness has until recently posed a serious obstacle to transportation and was a major constraint limiting development. Much of the area is now being opened up through the construction of all-weather roads which provide greater access to many of the small farms in northern Huehuetenango and northern Quiché as well as to towns in Baja Verapaz and Alta Verapaz. It is anticipated that these will be areas of rapid agricultural and economic development over the next five to ten years.

Climate

Most of the western highlands enjoy a cool, invigorating climate due to the altitude differential. Temperatures in the highlands present an enjoyable contrast to the heat found in parts of northern Guatemala and along the southern coast. Although the average altitude for the region ranges from about 2,100 to 2,700 msnm, parts of Chimaltenango (and Sacatepequez which might well be considered as part of the western highlands although it was not mentioned earlier as part of the region) are located as low as 1,500 msnm. Many of the volcanic peaks and the tops of the Cuchumatanes Mountains, on the other hand, reach altitudes in excess of 3,300 msnm, with some peaks reaching more than 4,000 msnm.

Precipitation

Weather patterns in the western highlands display two distinct seasons. The rainy season begins about the first of May and lasts until the middle of October. The heaviest rains generally occur in the months of June, August, and September. The dry season begins in October or November and lasts until the next May with the driest months being January, February, and March. Morán Burgos (*ca.* 1970, p. 44) estimates that 60% of the region he identifies as the western highlands would be typified by the above described pattern and that an additional 30% of his area is typified by having a dry or variable dry period from December through March which is followed by a rainy season from April to October with maximum rainfall occurring in the month of August.

The average amount of precipitation for most of the region is between 1,500-2,000 mm per year. In some areas, much of this moisture comes in the form of dew and fog which condenses upon the vegetation. Anyone who has ever tried to drive from Quezaltenango to Sololá on a foggy night can appreciate how fog might contribute substantially to total mm of precipitation. While average precipitation is about 1,800 mm, there is quite a large variance associated with this average in selected areas. Parts of central San Marcos may receive over 4,000 mm annually while northern parts of Chimaltenango might receive only 1,000 mm.

Temperature

Normal temperatures vary considerably with the altitude. Quezaltenango at about 2,500 msnm is invariably cooler than Guatemala City at about 1,500 msnm. The mean annual temperature of the western highlands will be between 12^{o}-16^{o}C. Summer average temperatures vary from 1.5^{o}-2.5^{o}C higher and winter average temperatures are about 2^{o}-3^{o}C lower. Temperatures seldom are registered above 21^{o}C or below 3^{o}C in this area (Morán Burgos, ca. 1970, p. 43). Frosts are quite common at higher altitudes from December until March.

Cultural Characteristics

The western highlands has traditionally been regarded as "la tierra del indigina" or as the home of the indigenous peoples generally recognized as the descendants of the Mayas. After the decay (disappearance might be a better term) of the Mayan culture, the highland Indians came under the control of various Mexican conquerors who, as the years went by, were largely assimilated by the local cultures. At the time of the Spanish Conquest, no single homogeneous Indian culture existed. During Spanish colonial times authorities divided native populations into municipios or townships. Whether this was done arbitrarily or in accordance with existing tribal and cultural delineations is not clearly understood. In any event, tribal groupings after this were replaced by a system of approximately 315 municipios (Dombrowski et al., 1970, p. 77). As a consequence of this division, the Indian ethnic groups today are composed of hundreds of communities with cultural similarities, but each municipio is a distinct cultural entity. Each municipio has its own customs, economic specialties, patron saints, costume, special festivals and market days. Even the language spoken in a municipio can be considered unique in the sense that Indians speaking the same language and dialect usually have at least slight differences in local vocabularies.

Languages

In addition to Spanish which is understood, if not spoken, by most people living in larger towns, the 1950 census listed fifteen Mayan languages which were being spoken in Guatemala. Today, four of these fifteen continue to be spoken by fairly large numbers of people in the western highlands. These four are Quiché, Cakchiquel, Mam, and Kelchi. Some of the other languages listed in 1950 continue to be spoken, but they are of relatively less importance today.

Each of the Indian languages is linguistically distinct as opposed to being a dialect of a common tongue. An Indian may speak two or more of the indigenous languages if other municipios near his home use them. In general, however, the common language for Indians from different linguistic groups will be Spanish. Most Indians know enough Spanish to be able to carry on whatever social and economic contacts they have with people outside their village, although it would be incorrect to assume on this ground that they are truly bilingual.

The linguistic diversity found among the Indian municipios has been one of the more serious literary barriers. Few teachers are fluent in an Indian language; most are Ladinos and have no interest in learning an Indian language. As a result, schools have become one of the primary places to learn Spanish, and teaching of Spanish is one of the school's primary objectives. Unfortunately, many Indian parents have not appreciated the importance of Spanish or for that matter the importance of schools. When one of the most visible results (to the parents) of schooling was an eight or nine year old child who could speak Spanish whenever he did not wish his parents to understand his conversations with friends or siblings, many parents decided that school was not as important as they had been led to believe. Consequently, some parents have been reluctant to have their children attend schools.

Communications between Ladinos and Indians are hindered both by the language barrier and by the assumed superiority which each group feels toward the other. Many people are aware that some Ladinos have this attitude and have seen instances in which actions of Ladinos display their assumed superiority. This attitude is not as readily observable among the Indians but it does exist. This is not surprising because the worlds of the Indian and the Ladino are in many ways quite dissimilar. This is changing, but in the past the Indian has viewed his community as quite literally the center of his world. He did not recognize the municipio as an integrated part of a larger national entity. It is important to recognize that for the Indian, the municipio has been a closely integrated society bound by strong ties of religion and tradition. His language, local costume, the economic specialization of his municipio, and his local culture all reflect the fact that he considers himself to be different from other Indians and certainly different from Ladinos. As a fellow human being, his view of himself as being different would naturally enough be accompanied by his view of himself as being superior. This view has helped to preserve the Indian culture to date, and it is in part desirable because one of the most important and difficult tasks of development is to find ways to preserve local cultures and at the same time to foster economic development. It is generally agreed in principle that ways need to be found to merge local cultures and modern technology to make the process of development a smooth and orderly one. Unfortunately, it is often easier to embrace the principle than to accomplish the task.

Economic organization

The Guatemalan Indian appears to be somewhat of an anomaly among peasants. Applegate (1973, pp. 99-102) points this out by referring to the differences in the findings of Tax (1963) and Rogers (1969) with reference to the characteristics of a peasant. Rogers attempted to synthesize what is currently known about the values, attitudes, and motivations of subsistence farmers. His findings presented a rather pessimistic picture of peasants as candidates for agricultural and economic development. Tax, on the other hand, pictures the Guatemalan peasant as behaving in many respects almost like a "capitalist," albeit on a very small scale.

> The Indians of Panajachel, and the people among whom they live and with whom they do almost all of their business, are part of what may be characterized as a money economy organized in single households as both consumption and production units, with a strongly developed market which tends to be perfectly competitive . . . because of the regional specialization of labor, it is also very strongly a market economy. (Tax, 1963, p. 13).

Evidently the peasants of Guatemala represent exceptions to the ordinary expectations of what a peasant is, does, and how he behaves. Redfield, in his discussion of Guatemala, observed that conventionally the typical peasant village had been described as one in which there is no quest for gain within the circle of those bound together by religious ties, and that in such a society the village is one big family, united by piety and holding property communally. He goes on to say:

> These particular Guatemalan societies are about as far from such a condition as is our own. The Rule of the Market has entered even within the most intimate group. Neighbors buy and sell from one another. The price of goods within the village is the same as the price in the market center, allowance being made for savings in labor or transportation or the like. (Redfield as cited by Whetten (1961).)

Whetten, writing in 1961, suggested that some of the differences between Guatemalan and other peasants might be explained by the relative scarcity of arable land in many highland regions.

> Arable land is so scarce in the highland regions of Guatemala that not all municipios are able to produce enough of the basic milpa (maize) to support the population. This factor, coupled with tradition, has led to a high degree of specialization among the Indians, not only in handicrafts and labor, but also in crops. (Whetten, 1961, p. 108).

It is important to realize that while the Guatemalan peasant's life and culture are built around the cultivation of corn, he is usually not merely a subsistence farmer.

> Each township has an economic specialty consisting of particular crops, handicrafts, trades, marketing or labor. The choice of a specialization is often determined by the variation in altitude, natural resources, or the quantity or quality of land; however, similar geographic components do not produce the same economy, and the specialty in many

> communities derives simply from tradition or inventiveness. Townships within the same region do not necessarily specialize in the same general occupation. All communities grow corn . . . (Dombrowski et al., 1970, p. 80).

The highland Indian economy involves more than peasant agriculture. If we wish to influence the level of incomes in the highlands, it would appear that we should be studying the total economy as well as the (highly important) agricultural sector. Perhaps a good way to begin this study would be by constructing a set of village (or regional) accounts designed to collect data on the village (or regional) economy much as a system of national accounts provides data on the national economy. When we have a better idea of how the peasant economic system works, we may discover additional policy instruments which could be used to favorably influence target variables. This point is probably of importance for most peasant economies, however dissimilar, and is not intended to be representative of only Guatemala.

CHAPTER III. THE LINEAR PROGRAMMING MODEL

The Choice of An Analytical Technique

The general objective of this study is to develop an analytical framework (or model) which can be used to estimate the potential effects of agricultural development programs upon small farmers. The major specific objective is to estimate the potential effects of the Basic Grains Program on small farm income and employment levels. The analytical technique chosen to accomplish these objectives must satisfy three general criterion. First, it should be capable of generating solutions for all relevant cropping, resource set, and technology level combinations. It must be able to do this quickly and at a reasonable cost. Second, it should be capable of estimating which of the farmer's resources are most limiting. These estimates need to be made within a consistent logical framework that allows inclusion of all relevant production activities. Such information will make it possible to suggest programs to increase the availability of constraining resources. Third, the technique must be flexible enough to capture all essential aspects of small farm production in western Guatemala.

Linear programming (LP) is the analytical technique which comes the closest to fulfilling these requirements. LP models are capable of considering many diverse types of production and nonproduction activities, can be designed to allocate large numbers of different resources between equally large numbers of production activities in order to achieve a specified objective, and can be run at comparatively low cost. Linear programming models can usually be made as flexible and realistic as the problem demands, provided that the model builder thoroughly understands the production process. Furthermore, LP models can be solved using conventional computational techniques and are therefore comparatively easy to use.

Linear programming is particularly appropriate for the present analysis because of the ease with which the model can be adapted to analyze the effect of new technologies and changes in the farmer's set of resources. New technologies at the farm level are usually embodied in new production activities. Thus for the farmer, the choice of which technology to employ reduces to a choice between alternate activities in which the new activities compete with older activities for the farmer's resources. The farmer's goal is to select that set of activities which will maximize his net income subject to whatever constraints are imposed by his limited set of resources, his personal desires, and existing institutions.

In this study, the farmer's set of resources is defined broadly so that knowledge of agricultural technologies can be included as a resource. Each farmer has a certain store of knowledge just as he has a certain amount of savings, land, labor, etc. As the farmer becomes aware of a new technology, his knowledge increases. Or alternately, new technologies require more knowledge. Increments in knowledge which accrue to the farmer as a result of his participation in extension activities can be incorporated into an LP model by parametrically adding to the farmer's total supply of knowledge. In this way, the additional knowledge needed for activities embodying new technologies is made available. This additional knowledge allows newer activities to compete with older activities for scarce resources, and the model yields estimates for the effect of these new technologies on farm income and employment. Knowledge is, however, only one of several important resources whose scarcity can limit farm income. Land, labor, and working capital must also be available if production is to take place. In Chapter V we will see how these resources are combined, recombined, and analyzed to determine their relative importance.

The juggling, testing, and recombining of farm resources which will be carried out in Chapter V involves more than simply seeing how a farmer's income and employment levels are altered by a change in his set of resources. It is also necessary to consider why and how the farmer's set of resources is going to be changed. Most small highland farmers are probably not capable of significantly changing their existing set of resources. Any major changes would require outside intervention, probably from Government agricultural development programs. By solving the model with various sets of farm resources, it is possible to estimate the farm level effect of successful Government programs designed to increase the farmer's supply of certain resources. Such estimates are often valuable in deciding which, if any, Government programs should be undertaken.

For example, a Government planner may need to choose between: (1) an extension program designed to increase the farmer's supply of knowledge; (2) a credit program designed to increase the supply of capital; (3) a land reform program which would alter the average size of farm; (4) a migration incentive program which would alter the local supply of hired labor; or (5) some combination of the above programs.

The linear programming model could aid the planner in his decision by pointing out which factors are in shortest supply now, and which would be in shortest supply if one or a combination of these programs were successful in increasing resource supplies. The linear programming model can also be very helpful in identifying and quantifying program targets. Targets help clarify program goals and are an important aid in program evaluation.

The Linear Programming Model

Over the past fifteen years, linear programming has become a widely known technique for agricultural planning at both the micro and macro levels. To give a detailed explanation of the method here would be redundant, and the reader is referred to Heady and Candler (1958); Dorfman, Samuelson, and Solow (1958); Hadley (1962); or Dantzig (1963) for a more extensive treatment.

The maximization form of the linear programming model may be expressed by the following equations:

Maximize

$$Z = \sum_{i=1}^{n} c_i x_i \tag{1}$$

subject to

$$\sum_{i=1}^{n} a_{ji} x_i \leq b_j \tag{2}$$

and

$$x_i \geq 0 \tag{3}$$

where

Z = the value of the program

x_i = activity i (i=1, 2, ... , n)

c_i = the net contribution to Z of activity i

b_j = the quantity available of resource j (j=1, 2, ... , m)

a_{ji} = the amount of resource j needed for one unit of activity i.

Equation (1) is the objective function. Equation (2) is a shorthand notation for the group of constraint equations and transfer rows which make up the heart of the linear program and specify that no more resources can be used by the activities (x_i) than are present in the resource base (b_j). Equation (3) specifies that all activities (x_i) can only take on non-negative values.

Linear programming is particularly useful for farm planning studies because it is a flexible tool and can be easily adapted to a wide variety of farming situations. It has been applied successfully to studies of large highly mechanized farms in the United States, to studies of collective farming in Eastern Europe and to studies of cooperative farming in South America. It is equally adaptable to the almost completely non-mechanized farming practices of small farmers in the Guatemalan highlands.

The objective function

In farm planning models the objective function is generally to maximize some income variable such as gross income or net income, although in some cases the objective function may call for the maximization of total production or of employment rather than of income. The present analysis seeks to determine: (1) what is the maximum income that a small farmer can earn from his traditional set of crop production and labor sales activities; and (2) by how much could income be increased if that set were expanded to include activities embodying new high yield technologies. Consequently, the objective function chosen for the analysis may be expressed as:

$$\text{Max } Y = \sum_{i=1}^{n} p_i A_i$$

where

Y = net farm income

p_i = the net price of activity i

A_i = the level at which activity i enters the solution.

The linear programming matrix

The linear programming matrix consists of 59 rows and 70 columns. The rows fall in five classes. Class 1 is the objective function which occupies the first row. Class 2 consists of 25 rows which contain the resource requirements for the production activities and the amounts of the various resources the farmer has at his disposal. Class 3 contains two rows representing a psychological constraint. Class 4 consists of four rows which limit the sale of family and farmer labor. Class 5 consists of 27 transfer rows of different types.

The columns are divided into eight different classes. Class 1 consists of 21 crop production activities. Class 2 is made up of twelve crop selling activities. Class 3 contains eight activities which allocate savings and labor resources to the appropriate transfer rows. Class 4 is eight activities which hire in or use family and farmer labor. Class 5 consists of four activities used to hire in local labor. Class 6 contains ten labor sales activities. Class 7 is made up of four capital borrowing activities, and Class 8 consists of three accounting activities. The matrix is constructed in such a way as to allow almost the entire analysis to be done using the same basic matrix while varying the farmer's set of resources. The complete LP matrix is presented in Appendix B. Appendix B also contains tables describing the rows and columns.

Assumptions of linear programming

One of the crucial factors underlying the choice of an analytical technique is the appropriateness of its assumptions. If these assumptions are not appropriate, neither is the technique. Fortunately, the assumptions of linear programming are appropriate for small farm production methods in western Guatemala.

Additivity and linearity. The assumptions of additivity and linearity require that when several productive activities are used together, their total product must be the sum of their individual products. Similarly, the combined input requirements for several activities performed together must be equal to the sum of the input requirements if these activities were performed separately. In essence, this means that no interaction is possible in the amount of resources required per unit of output regardless of whether the activities are produced alone or in various proportions (Heady and Candler, 1958). Consequently, all linear programming activities must be characterized by constant returns to scale. In most cases, agricultural activities conform to this requirement. This assumption might be a problem in a rotation activity where interaction could take place between, for example, corn and beans grown in different proportions. This problem is usually resolved by defining each rotation as a distinct activity characterized by different input requirements and different outputs than are found for either corn or beans alone. This example illustrates the flexibility of linear programming even though the assumption of additivity and linearity does not coincide exactly with the reality of all agricultural activities.

Divisibility. This assumption states that activities can enter the program, products can be produced, and inputs can be used in fractional units. That is, resources and products are considered to be continuous or infinitely divisible. The assumption of divisibility may cause difficulties if production activities are defined as very large, whole production units. For example, it would be awkward to have an optimal production plan that calls for 0.5 steel mills or 0.157 petroleum refineries. In agriculture, the assumption of divisibility has not proved troublesome. For activities such as livestock production in which answers expressed as whole numbers are desirable, it is usually possible to define the productive activity on a scale which minimizes this problem. For instance, by defining animal raising activities in terms of 100 head of hogs or cattle, a result of 0.431 cattle units and 0.677 hog units can be rounded to 43 cattle and 68 hogs which usually solves the problem. The assumption of divisibility creates no particular problems in the present analysis. Most of the inputs and outputs being considered are for practical purposes divisible; any indivisibilities that exist can be resolved by rounding to the nearest whole unit without causing serious errors.

Finiteness. Linear programming requires the assumption that there are a limited number of relevant activities and resource restrictions. This is a very practical assumption which causes no problems. The model used in this analysis contains 70 activities and 58 constraints.

Single-value expectations. This assumption states that individual resource supplies, input-output coefficients, and prices can be specified as a single value and that variations from this value can be ignored. Although often a little unrealistic, this assumption is acceptable for the purposes of the present analysis in which no attempt is made to determine how farmers respond to different degrees of risk associated with various crops.

Advantages and limitations of the linear programming model

The primary advantage of using linear programming as a farm planning or farm policy tool is that it allows the farm manager or the policymaker to consider a wide range of alternatives quickly and at a comparatively low cost. The principal limitations of the linear programming model are: (1) programming offers no help in formulating price expectations; (2) accurate production coefficients can be quite difficult to obtain; (3) programming cannot substitute for incomplete knowledge of the production process; (4) all programming activities are treated as being equally risky; and (5) activities which involve decreasing costs cannot be accurately treated (Beneke and Winterboer, 1970).

Resource Availabilities and Constraints

The primary resources the small farmer has at his disposal are land, labor, capital, and knowledge. Each of these resources is present in finite amounts and, consequently, represents a constraint in the linear programming model. In addition to these quantitative constraints, the model includes one natural and one psychological constraint. The natural (seasonality) constraint limits the timing of production activities in the model and results in all farm jobs and most resources being allocated to a specific quarter of the year. The psychological constraint limits the amount of time which the farmer is willing to devote to migratory labor sales activities.

There are also two minor constraints. The first is a constraint on local demand for farmer and family labor which prohibits both farmer and family from selling more labor than they possess. The second is a constraint on the amount of local labor which may be hired to assist with crop production activities. No more than ten men are assumed available for full-time employment. For most small farm operations this would be equivalent to giving the farmer access to an infinite supply of local hired labor. All other rows in the model are transfer rows of one type or another.

<u>The crop year</u>

Weather is one of the most important factors influencing any agricultural endeavor. Probably the most often cited effect of weather is its effect upon yield levels. Our interest here, however, is not directed toward the effect of weather on yield levels, but rather toward the broader and more permanent constraint which weather places upon growing seasons.

In order to more realistically determine resource restrictions, particularly for labor resources, the crop year was divided into four quarters which coincide approximately with the growing seasons for traditional crops in the western highlands. All resource supplies and resource requirements for both cropping and labor sales activities in the model are specified quarterly. The months falling into each of the four seasons or quarters are:

(1) first quarter--March, April, May

(2) second quarter--June, July, August

(3) third quarter--September, October, November

(4) fourth quarter--December, January, February.

In most highland areas, first quarter is the time for planting traditional crops. Exact planting dates depend on local variations in rainfall patterns, but it is usually correct to say that the first rains will begin in March or April. Planting usually takes place as soon as the first heavy rains have fallen. Second quarter is primarily a time of crop growth and development, cultivation, and disease or insect control. Third quarter is a period of maturation and of harvest for some crops as well as a period in which many highland farmers migrate to work on cotton, coffee or sugar cane farms for a month or two. Fourth quarter will be dedicated to harvest activities, farm planning, migratory labor sales, and some land preparation activities on larger farms.

Labor

The primary source of labor on small highland farms is the family. It is assumed that the typical highland farm family unit consists of farmer, wife, son, and daughter. Following the example of Gollas (1970, p. 42), family labor resources are divided into two categories: farmer labor; and family "farmer equivalent" labor. Gollas classifies and weights family labor in the following way:

(1) Males between the ages of 16-55 are given a weight of 1.0.

(2) Females between the ages of 16-55 are given a weight of 0.5.

(3) Children under 16 and men and women over 55 are given a weight of 0.3.

Farmer labor resources available on a quarterly basis are computed by counting the number of days in each quarter, subtracting the number of Sundays and multiplying by eight hours a day. The family's "farmer equivalent" labor resources are calculated by substituting the number of farmer hours available in each quarter into the following formula:

FET = 0.5 FT + 0.3 FT + 0.3 FT

FET = family "farmer equivalent" hours.

FT = total farmer hours available in the quarter.

The contribution of the wife to the total number of "farmer equivalent" hours is represented by the 0.5 weight while the contribution of the son and daughter are represented by the two 0.3 weights. This method of calculating labor time available for cropping or labor sales activities results in the quarterly labor resource limits shown in Table 3.1.

In addition to farmer and family labor, one version of the model allows hiring up to ten men. A farm probably would have to be over five hectares before as many as ten men were needed. This would be a comparatively large farm; the 1964 census reported that 87% of the farms in the country were smaller than two hectares (Fletcher _et al_., 1970, p. 60). Wages for hired laborers are quite low. The model allows local labor to be hired in at the rate of 7.6 cents per hour or Q0.608 per day which is a typical wage rate for most municipios in the western highlands.

Land

Land resources available to small farmers in the western highlands are quite limited both in terms of quality and quantity. Simmons' soil reconnaissance study (Simmons _et al_., 1958) divided highland soil types into three categories: good, poor, and not arable. Simmons estimated that only 74.2% of total land area in the nine highland departments was actually highland; 9.1% was classified

Table 3.1. Quarterly labor resource limits

Quarter	Farmer hours	Farmer equivalent hours
MAM	632	695
JJA	632	695
SON	624	686
DJF	616	678

as coastal land, and 16.7% was classified as tropical land (see Table 2.4). If only the highland areas are considered the data in Table 2.4 shows us that only 14.8% of the total highland area could be considered as good land. The remaining 85.2% is composed of 47.6% poor lands and 37.6% not arable lands. Obviously, the quality of land found on the typical highland farm is not very high. Initially, it was hoped that interview data on yields per hectare could be obtained for each of the different soil classifications Simmons identified. Unfortunately, this did not prove to be possible, and the only soil quality variable on which information could be obtained was slope. This information has been used to the fullest extent possible. The crop production activities in the model specify whether they require flatter more fertile valley lands, steeper poorer hilly lands, or a combination of valley and hilly land indicating that the activity is carried out on both better valley and poorer hilly soils.

The existence of two types or qualities of land presents a problem. What should be the proportions of good and poor land on a representative highland farm? If the land which Simmons categorized as unarable land was not farmed, then 23.8% of the land in farms would be good land and 76.7% would be poor land. These proportions could be used to define the relevant percentages of good and poor land on the typical farm. There are two reasons for not using this method. First, the production survey data used here did not provide information on the soil types used by Simmons. It is therefore possible that some of the activities identified in the survey as being carried out on good (flat) land might have been carried out on poor land by Simmons' classification. This is really quite likely considering the high percentage of poor land. Second, it seems likely that the Basic Grains Program will initially reach those small farmers with more than an average amount of good land. This is suggested by the program's goal to help a typical farm family earn at least Q1000 per year. Consequently, it was decided to assume that 50% of the farmer's total land is good valley land and 50% is poorer hilly land. This choice preserves the survey's distinction between good and poor lands. It also gives the farmer a higher proportion of good land than Simmons' study suggests. Thus, the Basic Grains Program is given the benefit of the doubt in its attempt to reach the aforementioned target level for family income.

The model specifies two other types of land in addition to the good and poor land mentioned above. These are vegetable land and potato land. Vegetable land is limited to one cuerda (0.04 ha) because: (1) the farmers in the western highlands are primarily producers of traditional crops, not of vegetables (although vegetables may be grown as an additional activity); and (2) vegetables require more water than do field crops and, hence, must be grown close to water. This is discussed further in Chapter IV.

The potato land constraint allows potato activities to be readily included or excluded from the set of production alternatives. This is done primarily because potatoes, like vegetables, cannot be grown everywhere with equal success. Potatoes do better at higher altitudes (2,500 msnm) with good quality lighter soils and adequate water. Obviously, not all areas will be appropriate for potato production. This distinction has been built into the model by including a potato land constraint. The three highest yielding potato activities are assumed to require land that is appropriate for potato production, i.e., land possessing the proper combinations of altitude, soils, and water availability which will enable the new varieties to produce the high yields specified in the model. At present potatoes tend to dominate other crops thus forcing them out of the model. Inclusion of the potato land constraint allows us to estimate the income earning potential which new technologies hold for the farmer who cannot grow potatoes, as well as for those who can.

Working capital

Working capital is often recognized as one of the most constraining resources for small farmers in developing countries. Guatemalan farmers do not appear to be an exception, which is one of the reasons for the Basic Grains Program. One of the major objectives of the Program is to relax this capital constraint. The thrust of the Program may be summarized by saying that BANDESA provides small farmers with credit and the "promotores" of DIGESA teach them how best to use it. In the model, working capital is assumed to be available from personal savings, as well as from the Government-sponsored small farmer agricultural credit program.

Personal savings levels of Q50 and Q150 are used in the model. Savings are assumed to be available for crop production at an opportunity cost of 5%. These two savings levels are used to show how important credit is for small farmers who do not have access to Government credit programs.

Government credit is assumed available at an interest rate of 10%. Loans are normally made in January and February with repayment required when the crop is harvested and sold. The exact repayment period depends on the length of the growing season and is therefore determined by both the specific crop and the borrower's locality.

Loans are assumed to be crop specific. Farmers are allowed to borrow up to Q450 for a hectare of potatoes but only Q80 for a hectare of corn or milpa. This restriction is imposed by the way in which BANDESA makes loans to small farmers. The farmer must contact a "promotor," extension agent or other representative of BANDESA to obtain a loan. He and the representative discuss where he lives, how much land he has and what crops he wants to grow. The loan is then made specifically for those crops. In almost all cases the amount of the loan will be adequate; the farmer will be able to buy most or all of the chemical inputs required for whatever level of technology he might wish to employ. There is, however, a maximum loan for each crop. This maximum is set by agronomists and others working for BANDESA, and their recommendations are periodically distributed to field representatives. The maximum loan size used in the model for each crop is presented in Table 3.2. The amounts were derived from a series of tables showing number of loans, total value of loans, and total loan area cultivated for the year 1972 and the period from January to August, 1973 (BANDESA, _ca_. 1973a and BANDESA, _ca_. 1973b). The tabled amounts are the amounts approved, and may not have actually been disbursed. Nevertheless, they provide reasonable estimates of the amounts BANDESA will loan to small farmers.

Knowledge

The current Basic Grains Program recognizes the importance of knowledge as a productive resource in agricultural production. For this reason, both the provision of knowledge through extension activities and the provision of credit through lending activities have been specified as dual objectives of the Basic Grains Program.

Table 3.2. Average loans per hectare for traditional crops[a,b]

Crop	Loan per hectare (Q)
Milpa	80
Corn	80
Wheat	110
Potatoes	450
Vegetables	450[c]

[a]BANDESA, ca. 1973a and BANDESA, ca. 1973b.

[b]The average loan size per hectare is assumed to be representative of the guidelines used to specify the maximum loan size per hectare.

[c]The maximum loan per cuerda will be Q19.65 for vegetables. Farmers are only allowed to grow one cuerda of vegetables in the model. Those with larger amounts should probably be classified as vegetable producers instead of traditional crop farmers.

Knowledge and new technologies appear at the farm level as new production activities. As the farmer's knowledge of new technologies grows, he has a greater variety of cropping activities to choose from. Four levels of crop knowledge are defined for this analysis. These are all or none propositions. The farmer either possesses the knowledge resources needed by an activity embodying a new technology, or he does not. Each level of crop knowledge is built into the LP model as a constraint, and each cropping activity requires a specific level of crop knowledge.

Corn, milpa, and wheat activities are classified into three technological levels. These are: (1) a traditional or present day lower technology characterized by low use of agricultural chemicals; (2) a present day intermediate technology characterized by use of some fertilizer but little else; and (3) a present day high technology in which farmers use more fertilizers, increase their planting density and use insecticides, herbicides and fungicides as recommended by extension agents and others. Technology level (3) is currently used on most demonstration plots.

Potato production activities are classified into four levels of technology. The first three are roughly comparable to the levels outlined above. The first may be classified as a low traditional potato technology. The fourth or highest of the potato activities, PV4, is definitely higher than the level of technical knowledge required for other crops. PV4 requires a crop knowledge level of TL3, which is the highest level of technical expertise required by any of the farmer's cropping activities.

In addition to the knowledge resources mentioned above, the farmer may possess knowledge needed for vegetable production. Here also there are differences in the amount of knowledge required for different crops. Early and later beets require the equivalent of a traditional knowledge input because they are comparatively easy to grow. Onions, early carrots, and later carrots require an intermediate knowledge input. This distinction was made because onions and carrots are much more profitable than beets, indicating that fewer people have been able to grow them. By alternately granting and then taking away knowledge resources needed to grow onions and carrots, we can see how income, employment and the composition of crops produced are altered by including vegetables among the farmer's set of production activities.

The effect of the Government's extension program upon a participating farmer is estimated by running successive solutions of the model. In the first run the farmer is assumed to possess only traditional knowledge. His alternatives are, consequently, limited to only those production activities requiring traditional knowledge. In the second run he is given both present day intermediate and traditional knowledge which allows him to include activities requiring an intermediate level of crop knowledge in his set of cropping activities. Subsequent runs enlarge his store of knowledge resources and, consequently, enlarge his set of cropping activities.

Use of knowledge as a constraint is not too common in linear programming. Consequently, it may be helpful to consider an example which demonstrates how knowledge is built into the model as a constraint. This has been done in Table 3.3. Table 3.3a presents the complete set of crop and vegetable production activities included in the LP model and identifies the level of crop or vegetable knowledge which each activity requires. Tables 3.3b and 3.3c present excerpts from the LP matrix (which is presented in Appendix B) that

Table 3.3a. Level of knowledge required by crop and vegetable activities

Activity[a]	Knowledge level required	Activity[a]	Knowledge level required
MH1	TL0	WV4	TL2
MH2	TL0	PHV1	TL0
MV1	TL0	PHV2	TL1
MV2	TL1	PHV3	TL2
MV3	TL2	PV4	TL3
CV2	TL0	EB	Low (0)
CV3	TL1	LB	Low (0)
CV4	TL2	GO	High (1)
WHV1	TL0	ECR	High (1)
WHV2	TL0	LCR	High (1)
WV3	TL1		

[a]Crop activities are identified by crop, by type of land they require, and by the relative amount of working capital they require according to the following code: M=milpa; C=corn alone; W=wheat; P=potatoes; H=hilly land; V=valley land; HV=a combination of hilly and valley land; 1=very little working capital; 2=an intermediate amount of working capital; 3=a high amount of working capital; 4=a very high amount of working capital. Vegetable activities are identified by vegetable and by planting date according to the code: E=early; L=later; B=beets; GO=green onions; CR=carrots. These same codes are used in Tables 3.3b and 3.3c.

Table 3.3b. An excerpt from the LP matrix in which the farmer with one hectare of crop land has a crop knowledge level of TL1 and a low level of vegetable knowledge

Row name	Row type	Row no.	RHS[a]	Crop activities									Veg. activities		
				MH1	MV2	MV3	CV2	CV3	CV4	WHV2	PHV3	PV4	EB	GO	LCR
TL1[b]	L	54	1	0	1	0	0	1	0	0	0	0			
TL2[b]	L	55	0	0	0	1	0	0	1	0	1	0			
TL3[b]	L	56	0	0	0	0	0	0	0	0	0	1			
TLV[c]	L	57	0										0	1	1

[a] This column contains the right hand side values.

[b] Crop knowledge levels.

[c] Vegetable knowledge levels.

Table 3.3c. An excerpt from the LP matrix in which the farmer with three hectares of crop land has a crop knowledge level of TL3 and a high level of vegetable knowledge

Row name	Row type	Row no.	RHS[a]	Crop activities									Veg. activities		
				MH1	MV2	MV3	CV2	CV3	CV4	WHV2	PHV3	PV4	EB	GO	LCR
TL1[b]	L	54	3	0	1	0	0	1	0	0	0	0			
TL2[b]	L	55	3	0	0	1	0	0	1	0	1	0			
TL3[b]	L	56	3	0	0	0	0	0	0	0	0	1			
TLV[c]	L	57	1										0	1	1

[a]This column contains the right hand side values.

[b]Crop knowledge levels.

[c]Vegetable knowledge levels.

show how levels of crop and vegetable knowledge restrict the farmer's set of production activities. For example, in Table 3.3b, the farmer with one hectare of crop land and a crop knowledge level of TL1 has sufficient crop knowledge to grow one hectare of MH1, MV2, CV2, CV3, or WHV2. He could also grow a combination of the above crops which totals one hectare. He cannot grow MV3, CV4, PHV3, or PV4. In addition to these crops, he could grow one cuerda of early beets. He could not grow green onions or later carrots. In Table 3.3c, the farmer is given three hectares of crop land, a crop knowledge level of TL3, and a high (1) level of vegetable knowledge. His crop knowledge level will now permit him to grow three hectares of any crop (or combination of crops) plus one cuerda of any vegetable in Table 3.3c.

Psychological constraints

Only one psychological constraint has been included in the model. This constraint limits the amount of time the farmer is willing to spend working as a migratory laborer. As a result of this constraint, the farmer may not allocate more than 416 hours to migratory labor sales activities in either the third or fourth quarters. Thus the farmer will spend no more than 60 days working as a migratory laborer on cotton, coffee, or sugar cane farms in third or fourth quarter. This restriction is supported by Schmidt's (1968b) finding that most work contracts among migratory laborers were for 30 to 60 days. It was felt that here, as in the case of vegetable production, some type of restraint is needed to insure that the behavior of the farmer in the model roughly corresponded to the behavior of most small farmers. If we allowed farmers to migrate all year round (or to produce only vegetables), we would not be describing the realities of the situation. This is a model of small farmers who are primarily producers of corn, beans, wheat, and potatoes. This is the population the Basic Grains Program is directed at, and it is the population the "typical" farmer of our study is drawn from.

Prices Used in the Analysis

Two types of prices are used in this analysis. These are: (1) farm gate prices; and (2) Guatemala City average monthly wholesale prices. Farm gate prices are the prices received by the farmer if he sells his crop to local truckers. Guatemala City average monthly wholesale prices (as measured at the Terminal Market in Guatemala City) are an estimate of average wholesale prices in Guatemala. The difference between farm gate prices and wholesale prices should be moderate and should equal the cost of transportation plus a little extra to pay for market taxes, interest on the capital used in the operation, and a payment for the trucker's services. For most agricultural products in most areas of the western highlands, this difference was estimated as amounting to about Q0.50 per hundred weight in 1973. Information on 1969 transportation rates between Guatemala City and selected cities in the western highlands is given in Table 3.4.

Table 3.4. Transportation costs to Guatemala City from selected cities, 1969[a]

Department & City	Cost per qq[b] (Q)	Cost per mt (Q)
Sacatepequez		
Cuidad Vieja	0.25	5.50
Antigua	0.20	4.40
Magdalena Milpas Altas	0.15	3.30
Chimaltenango		
Chimaltenango	0.20	4.40
Perramos	0.30	6.60
Tecpán	0.35	7.70
Huehuetenango		
Ahuacatán	0.50	11.00
Huehuetenango	0.50	11.00
Quezaltenango		
Quezaltenango	0.35	8.80
Zunil	0.40	8.80
Huitán	0.40	8.80
Sololá		
Sololá	0.40	6.60
Santiago Atitlan	0.30	

[a]Ministerio de Agricultura, 1970.

[b]The transportation costs in this table were typical truck rates in 1969. Rates are undoubtedly somewhat higher today. In addition, rates may vary according to the type of product, condition of the road and the individual trucker.

Small farmers are usually willing to sell their corn, wheat, beans, habas, guicoy squash, ayote squash, and chilacayote gourds locally. Prices used in the analysis for these products are, consequently, local or farm gate prices, and no attempt was made to build marketing costs into the model's coefficients for these crops.

Potatoes may also be sold locally, but it is quite common for potato farmers to take their potatoes to the Terminal Market in Guatemala City. Most of the farmers interviewed did this, and consequently, the potato prices used are average wholesale prices. Transportation costs and labor requirements for the trip to the Terminal Market have been built into the model's coefficients.

Vegetables may be sold locally, taken to a regional market, or taken to the Terminal Market. It is assumed that the farmer takes them either to a regional market or to the Terminal Market. Again, the cost of transportation and the time required to effect this transportation have been included in the model's coefficients.

Four primary sources of data on prices have been used to estimate prices for the model. The first is sample data (Johnston, ca. 1973a) in which farmers were asked to estimate average prices received for their crops over a five-year period. These data are presented in Table 3.5. The second is a set of monthly average wholesale prices for the years 1966 to 1971 which were collected at the Terminal Market in Guatemala City by the staff of the National Agricultural Marketing Institute (INDECA, 1973). These prices are given in Tables 3.6 and 3.7. The third important source

Table 3.5. Farm gate prices reported by small farmers[a]

Crop	Average price (Q)	Unit
Corn alone	3.04	qq
Corn in milpa	4.30[b]	qq
Black beans	10.33	qq
Habas	9.74	qq
Wheat	5.71	qq
Mature guicoy	0.07	each
Ayote	0.07	each
Chilacayote	0.07	each
Potatoes	4.79	qq

[a]Johnston, 1973a.

[b]Farmers were asked to report average prices. The data indicate that for corn in milpa, some of them misunderstood what was wanted and reported actual present day (1972-73) prices. These prices were quite high due to the drought which destroyed much of the 1971-1972 corn crop. These high prices may also have caused some farmers to estimate that average prices were higher than they were. For these reasons it is felt that the corn price given here of Q4.30 per qq is a little high.

Table 3.6. Average wholesale prices, 1966-1971[a]

Crop	Month(s)	Price (Q)	Unit
Yellow corn	December-February	3.53	qq
Black beans	September-November	9.05	qq
Habas	September-November	10.55	qq
Chilacayote gourd	--	--	--
Ayote squash	January-December	0.076	apiece
Mature guicoy	September-November	0.088	apiece
Potato average price	September-November	4.70[b]	qq
Medium green onions	October	7.56	per 1,000
Carrots	September	2.20	per 25 dozen
Carrots	October	2.20	per 25 dozen
Beets	September	1.64	per 25 dozen
Beets	October	1.88	per 25 dozen

[a]INDECA, 1973.

[b]For additional information on potato prices see Table 3.7.

Table 3.7. Average wholesale potato prices, 1966-1971[a]

Variety	Month(s)	Price/qq (Q)
Alpha	September	4.75
Alpha	October	4.95
Alpha	November	5.66
Alpha	September-November	5.12
Voran	September	3.85
Voran	October	4.24
Voran	November	4.75
Voran	September-November	4.28
Alpha & Voran	September-November	4.70

[a]INDECA, 1973.

of price information is the set of tables, "Average Crop Production and Average Price Data," by Dr. James Walker (1968). These estimates contain information on prices during the 1964-1969 period consequently provide an important perspective for judging more recent price levels. They are presented in Table 3.8. The fourth source, which presents information on vegetable prices, is the report, Analisis de Actividades Necesarias para la Produccion de 11 Especies Horticolas (Hortalizas), (Johnston, 1973b).

The price differences shown in these tables are attributed to two factors. First, the sources quote price estimates for different time periods. Second, they report two kinds of prices. Farm gate prices in 1973 are shown in Table 3.5 while Tables 3.6 and 3.7 report on average monthly wholesale prices between 1966-1971. Table 3.8 estimates average annual wholesale prices for the 1965-1969 period.

The prices finally selected as representative average prices for 1973 appear in Table 3.9. Farmers could probably get somewhat higher prices than are listed in Table 3.9 if they held back their crops at harvest and waited for prices to rise. Some farmers do this, but it is not a realistic alternative for most small farmers.

Table 3.8. Average price estimates for Guatemalan crops[a]

Crop	Price (Q)	Unit
Corn	3.00	qq
Black beans	10.00	qq
Habas	12.00	qq
Wheat	5.85	qq
Mature guicoy	3.00	qq
Ayote	2.50	qq
Chilacayote	1.00	qq

[a]Walker, 1968.

Table 3.9. Average prices used in the analysis

Crop	Price/unit of measure (Q)	Unit of measure	Place of Sale
Corn	3.30	qq	Local market
Black beans	10.00	qq	Local market
Habas	10.00	qq	Local market
Potatoes	4.75	qq	Guatemala City
Wheat	5.75	qq	Local market
Guicoy or ayote squash	0.07	each	Local market
Chilacayote gourd	0.10	each	Local market
Early beets	0.065	doz.	Guatemala City
Late beets	0.07	doz.	Guatemala City
Green onions	7.00	1,000	Guatemala City
Early carrots	0.088	doz.	Guatemala City
Late carrots	0.088	doz.	Guatemala City

CHAPTER IV. RELIABILITY OF THE PRODUCTION DATA

Since the data used to construct production coefficients determine the validity of the model's estimates, it seems appropriate to discuss the types of data needed, the data collection procedures, and the reliability of the estimates made for yields and input requirements. Let us begin this discussion with a few observations concerning the overall quality and reliability of the data used in this study, and of Guatemalan crop production data in general.

The production coefficients used here are derived from data contained in the two studies, Producción De Cultivos Tradicionales En El Altiplano De Guatemala (Johnston, 1973a) and Analisis De Actividades Necesarias Para La Producción De 11 Especias Horticolas (Hortalizas)(Johnston, 1973b). The first study contains detailed crop production information obtained by interviewing small farmers. The farmers included in the survey were chosen as being representative small farmers by Ministry of Agriculture personnel, Peace Corps volunteers, and others who assisted with the interviewing. The sample was not a random sample; it was a judgment sample. The results are therefore dependent upon the judgment of the interviewers who selected the "representative" farmers. About half of the sample interviews were conducted by volunteers. This allowed an increase in the number of farmers to be interviewed and expanded the size of the sampling region. Unfortunately, the quality of the interviews conducted by the volunteers was not as high as had been hoped for, and some of the questionnaires were not as complete as they might have been.

It is recognized that the reliability and accuracy of the sample data are open to question. There are three main reasons for this: (1) the incompleteness of some interview questionnaires; (2) the non-random manner in which the sample population was chosen; and (3) the relatively small size of the sample. As a result, it is probably best to regard these data as first approximations or as benchmark estimates for the actual underlying production coefficients. Nevertheless, and in spite of these limitations, it is believed that the data are reasonably accurate and are a valuable source of information on small farm production practices, costs, labor requirements and materials. Furthermore, it is believed that the data are sufficiently reliable so that the model may be used to approximate the position of a small farmer, and, hence, to provide information for the policymaker on how Government programs and policies affect the small farmer and his farming alternatives.

The second study (Johnston, 1973b) was used to construct production coefficients for vegetable production. It consists of data drawn from interviews with from three to five vegetable production experts for each crop. These were in-depth interviews, and each one was followed up by a second interview in which the data obtained earlier was checked and verified. It is believed that the production coefficients derived from this information are quite accurate.

One of the most striking things about Guatemalan crop production data in general is how little there is of it. Considering the tremendous research effort which has been expended in Guatemala over the last 30 years one would expect to find much more and much better data than is presently available. Technicians have been aware of this problem for several years, and it appears that the need for generation of better data is being recognized as a priority research topic. There have been several plans and projects in recent years dedicated to formation of a data base that would provide information on production costs of small farmers. To date these plans have not been successfully completed, but it is anticipated that information on small farm production will soon be forthcoming. One of the more optimistic recent events signaling future availability of higher quality data was the creation of the new agricultural institute, ICTA (Instituto de Ciencia y Technologia Agricola). ICTA should play an important role in collecting, storing and generating information on small farm production practices, although ICTA certainly will not limit its attention to this one area. ICTA could become a very important source of research information for Guatemala. It is anticipated that the institute will become involved in a wide variety of studies and experiments pertaining to agricultural and economic development.

Types of Data Needed and Method of Data Collection

Four types of data are needed for a linear programming model. These are: (1) identification of the activities to be included in the model; (2) production coefficient data; (3) product and input price data; and (4) identification and specification of all relevant constraints. Let us examine each of these in turn.

The first step in constructing a linear program is to decide what is to be minimized or maximized, and what activities are to be included in the objective function. In the present context, the objective is to maximize net farm income, and the activities which will contribute to this objective are crop and labor selling activities. Obviously, one cannot have crop selling activities without crop production activities; thus, the first decisions to be made must be: (1) what crops will be produced; and (2) where and how much labor can be sold? The model presented in this study includes production activities for five crops: corn, milpa, wheat, potatoes, and vegetables. These crops were selected after consulting with agronomists and economists from the Ministry of Agriculture. In addition to their cropping activities, many small farmers earn part of their income by selling labor. Labor sales activities are of two types: local labor sale and migratory labor sale. Local labor sales usually consist of selling daily labor to larger landowners who need assistance with crop production activities. Migratory labor sales occur in the third and fourth quarters when many small farmers migrate to the piedmont and coastal areas to assist with the coffee, cotton or sugar cane harvests. There are, of course, other types of activities by which small farmers may supplement their incomes. These activities are not identified separately because, in essence, they are simply other ways of selling labor locally. As such, their contribution to family income will be subsumed in the local labor sales activities.

The second step in the model's construction was to estimate the production coefficients. The basic data for these estimates were obtained with a crop production questionnaire which was administered to small farmers. The questionnaire was designed to be as inclusive as possible. All steps in the production cycle were identified and divided into specific tasks. Corn production, for example, was divided into 22 separate chores. Not all farmers would do all 22, and the farmer was asked to select from the list only those tasks which he did in his field, and to tell: (1) how much time it took him to do each one; (2) the quantities of any materials he used; and (3) what he estimated the cost of the materials to be.

Interview booklets, each containing questionnaires for three crops, were distributed to Ministry of Agriculture personnel, Peace Corps volunteers, and other volunteers living throughout the altiplano. Interviews were conducted with sixty-two farmers living in twenty-six different municipios located in eight highland departments. The questionnaires were distributed and the interviews conducted during March, April, May, and June of 1973. Fifty copies of the survey results were distributed to technicians working in the areas of agricultural production and agricultural development in August 1973.

The third step in the model's construction was to obtain price data. Input price estimates were available from the sample data. Where the sample data was incomplete, missing information on input prices was estimated from data provided by agricultural supply houses in Guatemala City. Output price estimates relied quite heavily upon information supplied by INDECA, the National Agricultural Marketing Institute, and are discussed in Chapter III.

The final step was to determine resource availabilities and specify production constraints. The resources which the farmer has at his disposal include: land, labor, savings, and knowledge. Each of these resources imposes a constraint on the farmer's production alternatives. In addition, there are various psychological and institutional constraints which could limit the farmer's production choices. These were also discussed in Chapter III.

Examination of the Milpa and Corn Alone Activities

Milpa production is the most characteristic production activity of the western highlands. The term milpa means that corn is interplanted with squash and beans, and sometimes with a few potatoes as well. There are at least three types of squash that are interplanted with the corn: "chilacayote" (malabargourd), "ayote" (crook-neck squash), and "guicoy" (acorn squash). Black pole beans and "habas" (broad beans) are also interplanted with the corn. The exact mix of corn, squash, and beans depends upon the farmer. The most characteristic mix of crops is to find corn, black pole beans, habas, ayote squash, and chilacayote gourd in the same field.

The traditional land unit used in this region is the "cuerda." There are various sizes of "cuerdas" to be found, but the most common one is the "standard cuerda" containing 625 square "varas." The "vara" is the Spanish equivalent of the English yard, and one "vara" is equal to 0.914 yards. The "standard cuerda" is equal to 0.1079 acres or 0.04367 hectares.

When one speaks of milpa production, it is convenient to speak of production on a cuerda because not all of the crops grown are planted as densely as area would allow. For example, it is customary to plant corn on a one meter square grid with a meter between rows and a meter between hills. Generally black pole beans and/or habas are planted in the same hill with the corn. Somewhere in the cuerda will be one or perhaps two hills of chilacayote and two, or perhaps, three hills of ayote or guicoy squash. Corn is the principal crop in this group. Corn yields vary greatly depending upon natural fertility and the input package being used, but will often fall between 1.00 and 2.50 qq per standard cuerda or between 22.70 and 57.25 qq/ha. Bean yields are approximately 0.17 to 0.35 qq per cuerda (3.89-8.02 qq/ha) if you measure bean yield as being equal to production of black beans + production of habas. The cuerda will usually produce from 3 to 10 chilacayotes from each hill planted and from 3 to 10 ayote squash or 3 to 10 guicoy squash. The exact number of squash produced on the milpa depends to a large extent upon the number of hills the farmer decides to plant. There are farmers who engage in more commercial production of chilacayote, guicoy, and ayote, but their operations are quite different from the milpa we are describing here where squash are grown principally for domestic consumption. Corn and beans may more nearly be considered "cash crops" for the milpa farmer because some fraction of total production is often sold while the remainder is consumed by the family or fed to livestock.

To represent milpa production in the linear programming model, five distinct production activities have been identified. These activities are: (1) milpa production on hilly land requiring very little capital (Q22.87/hectare); (2) milpa production on hilly land requiring a moderate amount of capital (Q53.56/hectare); (3) milpa production on flat or rolling land requiring very little capital (Q20.35/hectare); (4) milpa production on flat or rolling land requiring a moderate amount of capital (Q54.47/hectare); and (5) milpa production on flat or rolling land requiring a relatively high amount of capital (Q79.66/hectare). It should be emphasized here that the data base these subdivisions are drawn from is quite small. Nevertheless, it is felt that these activities are a reasonable approximation to the types of productive activities carried on in the region as a whole. A better idea of the similarities and differences between the various milpa and corn alone activities can be ascertained by looking at Table 4.1b.

Table 4.1b also presents information on corn alone activities in which the beans, habas and squash characteristic of milpa production are absent. The sample data indicate that there are three distinct "corn alone" activities which can be identified. Two of these activities are currently being used by small farmers while the third (Activity CV4) is an activity promoted by Peace Corps volunteers, extension agents and others who are trying to demonstrate the potential yields to be obtained by using a package of inputs characterized by denser stand (fewer cm between plants and between rows, hence, more plants per hectare), heavier fertilization levels, use of insecticide to combat the root worm or grub called, "gallina ciega," and selection of an appropriate variety for the geographic region.

It is interesting to note that of the two "corn alone" activities being carried on today, one is a traditional method while the other appears to be an intermediate step toward the more capital intensive activity being recommended by extension agents and others. The traditional method may be characterized by low fertilizer use, wide spacing between plants and between rows, moderate labor requirements, moderate yields and spotty use of insecticides even though all the observations are from valley land where the gallina ciega is often a problem.

Table 4.1a. Definitions of column headings in Table 4.1b

Column no.	Column heads	Definition of column heads
1	Activity	This refers to a productive activity or a crop. The eight activities in Table 4.1b are all activities that involve growing corn. In the first five of these activities, corn is grown in a milpa while in the other three corn is grown alone. It is reasonable to regard each activity as a different crop because the input requirements (which often embody different technologies) vary between activities as do the proportions of outputs, the total value of outputs and cultural practices.
2	Capital class	This refers to the relative amount of capital required. The observations from the sample were divided into broad classifications regarding their use of capital. Capital class 1 was from Q0 to Q25 capital required per hectare. Capital class 2 was from Q25 to Q50 per hectare and so on.
3	YC	Corn yield in "quintales" (qq) or hundred weights (cwt) per hectare.
4	YB	Yield of black beans and habas. Since the price of beans and habas are equal, they are treated as a composite crop. Some farmers would grow all black beans and no habas while others would grow all habas and no beans or a mixture of habas and beans. In the linear programming model we take the yield found in column YB and assume that half this yield is black pole beans and half is habas.

Table 4.1a. (continued)

Column no.	Column heads	Definition of column heads
5	K1	The amount of capital needed in the first quarter.
6	K2	The amount of capital needed in the second quarter.
7	KT	The total amount of capital needed.
8	L1	Labor hours required in the first quarter.
9	L2	Labor hours required in the second quarter.
10	L3	Labor hours required in the third quarter.
11	L4	Labor hours required in the fourth quarter.
12	LT	Total labor hours required.
13	RLL	The dollar return to land, labor, and capital from this activity on one hectare of land. This is a net return; input costs are subtracted from the product of price and yield per hectare.
14	LBF	Quintales of fertilizer used. This includes the qq of urea used.
15	DR	Distance between rows measured in cm.
16	DP	Distance between hills of corn measured in cm.

Table 4.1a. (continued)

Column no.	Column heads	Definition of column heads
17	ID	Insecticide dummy variable--if the insecticide dummy has a value of 0, this means that none of the farmers used insecticide. If it has a value of 1, all the farmers used an insecticide.
18	TC	This represents total cuerdas. One hectare=22.9 cuerdas. This gives us an idea of the average farm size for farmers who indicated that they practice this activity.
19	TD	Topography dummy variable. A value of 0 indicates that all of the farmers said they farmed hilly or very steep land. A value of 1 indicates they all farm flat or gently rolling land. A value of 0.5 would indicate that ½ of them checked hilly or very steep and ½ of them checked gently rolling or flat.
20	No. of obs.	The number of farmers in the sample whose production is typified by the activity.

Table 4.1b. Milpa and corn alone produced on 1 ha of land[a]

(1) Activ-ity[b]	(2) Capi-tal class	(3) YC	(4) YB	(5) K1	(6) K2	(7) KT	(8) L1	(9) L2	(10) L3	(11) L4	(12) LT	(13) RLL	(14) LBF	(15) DR	(16) DP	(17) ID	(18) TC	(19) TD	(20) No. of Obs.
MH1	1	20.04	2.86	22.87	0	22.87	206	364	334	504	1408	88.45	0	80	65	0	12.75	0	4
MH2	2	22.90	8.59	53.56	0	53.56	206	364	334	504	1408	124.60	6.64	125	125	0	53.00	0	2
MV1	1	22.90	4.01	20.35	0	20.35	147	369	325	435	1278	112.01	0	125	113	0	6.5	1	2
MV2	2	50.52	3.46	48.29	6.18	54.47	147	369	325	435	1278	163.44	4.35	98	98	0.7	27.4	1	9
MV3	3	60.46	7.95	62.03	17.63	79.66	147	369	325	435	1278	216.05	8.24	93	70	0.3	91.3	1	3
CV2	2	32.52	0	17.83	22.90	40.73	112	231	32	309	684	66.59	3.78	110	110	0.5	66.0	1	2
CV3	3	50.38	0	54.69	23.13	77.82	112	231	32	389	764	88.43	10.49	100	58	0.5	66.8	1	6
CV4	4	122.74	0	111.49	45.57	157.06	112	231	32	389	764	247.98	16.95	90	25	1.0	-[c]	1	1

[a]Johnston, ca. 1973a.

[b]Activities are identified by crop, by type of land they require and by the relative amount of working capital they require according to the following code: M=milpa; C=corn alone; W=wheat; P=potatoes; H=hilly land; V=valley land; HV=a combination of hilly and valley land; 1=very little working capital; 2=an intermediate amount of working capital; 3=a high amount of working capital; 4=a very high amount of working capital. This same code is used to identify crop production activities in other tables of Chapter IV and throughout the thesis.

[c]Activity 8 information comes from corn demonstration plots conducted by the Peace Corps and the Ministry of Agriculture. The size of most demonstration plots is one cuerda.

Corn and bean yields in Table 4.1b

A careful analysis of Table 4.1b reveals that within the broad subject of "traditional corn production" there is considerable variation in yields, inputs, planting densities, and adoption of modern technology. Since the data in Table 4.1b is based on a very small sample of farmers, it must be used carefully. Table 4.1b provides an important source of information, but it is only one source. Additional work needs to be done to corroborate and improve upon the information presented here.

To begin with, how reasonable are the yield estimates contained in Table 4.1b? Yields in Table 4.1b range from 20.04 qq/ha on hilly land with no fertilization to 122.74 qq/ha on the demonstration plots run by the Peace Corps volunteers under the supervision of Dr. James Walker and personnel from the Ministry of Agriculture. This range of yields is a realistic expectation of what farmers could achieve in 1973. Corn yields have been increasing in the highlands over the past 15 years and, while a yield of 23 qq/ha or 30 qq/ha might have been high in 1960, it is quite reasonable in 1973. This view is upheld by the trend of corn yields presented in Table 4.2.

In the decade 1950-1960, the Bank of Guatemala estimated corn yields as fluctuating from a low of 14.31 qq/ha in 1955 to a high of 16.89 qq/ha in 1960. In 1961 the Planning Council estimated that yields had risen to 17.89 qq/ha and by 1964 FAO estimated in the publication, Estadisticas Mundiales de Cultivos, Roma, 1966,

Table 4.2. Corn yields, 1950-1973

Year(s)	Estimated yields (qq/ha)	Source	Additional information
1950-1960	14.31-16.89	Bank of Guatemala[a]	
1961	17.89	Planning Council[a]	
1964	24.61	FAO[a]	
1964-1965	25.50	Hill and Gollas[b]	Farmers using fertilizer in the Dept. of El Quiché.
1964-1965	11.90	Hill and Gollas[b]	Farmers not using fertilizer in the Dept. of El Quiché.
1966	30.0	Schmidt[c]	In the highlands.
1968	21.00	Walker[d]	National average estimate.
1968	31.46	Pérez[a]	Survey of 264 small farmers in western highlands. Pérez also found that farmers harvested 4.29 qq of black beans and 1.7 qq of habas or 5.99 qq of beans and habas.

[a]Pérez, 1971, pp. 76-81.

[b]Falla, 1972, pp. 30-45.

[c]Schmidt, 1969, p. 45.

[d]Walker, 1968.

Table 4.2 (continued)

Year(s)	Estimated yields (qq/ha)	Source	Additional information
1969	42.37	Falla[b]	Observations from farmers who use fertilizer, Dept. of El Quiché.
1969	16.03	Falla[b]	Observations from farmers who do not use fertilizer in the Dept. of El Quiché.
1973	20.04-60.46 (weighted average=40.39)	Johnston[e]	This is the range for corn grown in milpa. Bean yields in milpa range from 2.86-7.95 qq/ha.
1973	32.52-50.38	Johnston[e]	This is the range of corn yields for corn grown alone.
1973	122.74	Johnston[e]	This is an average yield taken from demonstration plots conducted by Peace Corps volunteers.

[e]Johnston, ca. 1973a.

that Guatemalan yields had increased to 24.61 qq/ha.

In about 1966, Lester Schmid did some field work for his Ph.D. dissertation. He found that corn yields in the highlands averaged 30 qq/ha (Schmid, 1968a). Hill and Gollas reported in 1968 that corn yields in the Department of El Quiché averaged 25.5 qq/ha for farmers who used fertilizer and 11.9 qq/ha for farmers who did not use fertilizer.

In 1968 Dr. James Walker (1968) compiled information on Average Crop Production and Average Wholesale Price Data for Guatemala in which he estimated that national corn yields in the country were about 21 qq/ha. Also in 1968, Francisco Samuel Pérez made a survey of 264 small farmers in the western highlands and found that within his sample the average production of corn was 31.46 qq/ha (Pérez, 1971). In addition, Pérez found that farmers harvested 4.29 qq of black beans and 1.7 qq of habas per hectare. If we add black beans and habas together, Pérez's data indicate that in 1968, on average, farmers produced 31.46 qq of corn and 5.99 qq of beans per ha.

In 1969, Father Ricardo Falla (1972), a sociologist at Rafael Landívar University in Guatemala City, spent a year studying adoption of "green revolution technologies" (particularly fertilizer use) in the "municipio," San Antonio Ilotenango in the Department of El Quiché. He conducted interviews himself and also trained locals in interview techniques in an effort to obtain data on population, church membership, education, and the economic situation of members of the local Catholic Action group. His interviews were limited to members of this group because of the suspicion and distrust which the Indian population displayed towards strangers. He was also able to obtain data collected by an agronomy student in the Canton of Patzala. In addition to these sources of information and his own informal conversations, he obtained data covering 46 soil analyses which came from various "cantones." His findings are presented in Tables 4.3 and 4.4. Comparison of Tables 4.3 and 4.4 with the data in Table 4.1b suggests a general agreement between the yield data for corn and beans. There is also general agreement with the yields of guicoy and chilacayote mentioned earlier in the text. Unfortunately, Padre Falla's data are not directly comparable with the data in Table 4.1b, because it does not contain information on insecticide use or planting density. Without this information, it is difficult to judge the seriousness of the discrepancies between these yield reports. Padre Falla's data do support the contention that among farmers who use fertilizer, corn yields are increasing over time. His reported corn yield of 42.37 qq/ha and bean yield of 6.87 qq/ha in 1969 is a step between the corn yield (31.46 qq/ha) and bean yield (5.99 qq/ha) reported by Pérez in 1968, and the yields reported in 1973 (for activities MV2 and MV3 which use fairly substantial amounts of fertilizer) of 53 qq/ha for corn and 4.58 qq/ha for beans (Johnston, ca. 1973a).

A weighted average of the data on corn grown in milpa (Table

Table 4.3. Comparison of the results described in the text regarding average production of corn and beans with chemical fertilizer[a]

Source	Corn qq/ha	Beans qq/ha	Fertilizer qq/ha	No. of obs.
1a. (Sacxac)	45.57	5.50	5.95	24
2a. (Patzala)	43.51	6.87	?	21
3a. (Suelos)	40.08	8.93	8.47	8
4a. (Informal)	43.51	6.41	?	20 for corn 13 for beans
Average	43.17	6.93		

[a]Falla, 1972.

Table 4.4. Average production with chemical fertilizer and without (the fertilizer used is 16-20-0)[a,b]

	Corn qq/ha	Beans qq/ha	Ayotes/ ha	Chila-cayotes/ ha	Cwts. fer-tilizer/ ha
With	42.37	6.87	57	57	7.56
Without fertilizer	16.03	2.75	0	0	0

[a]Falla, 1972.

[b]This table incorporates some additional observations in addition to the ones in Table 4.3.

4.1b) indicates that highland farmers achieved yields of 40.39 qq/ha for corn and 4.58 qq/ha for beans and habas combined. This is 8.93 qq higher for corn and 1.41 qq lower for beans and habas than Pérez (1971) found in 1968, but it is certainly in the same ballpark considering that five years of experience with use of newer technologies intervene between these two surveys. Similar comparisons cannot be made with Padre Falla's data because observations on the numbers of farmers not using fertilizers are unavailable.

If historical data on planting density of corn, yield of corn, yield of beans and habas, and use of fertilizers were available it probably would illustrate that as more fertilizer is used, planting density (or stand) can be increased. Increasing stand of corn means that there is less room to plant habas between the hills of corn and, consequently, haba yield per hectare would probably fall even though yield per plant may rise due to increased availability of nutrients provided by the chemical fertilizer. If this pattern is realistic, the differences between the 1973 survey results, Pérez's results, and Falla's results may be a reflection of this trend toward increasing the planting density or stand per cuerda. In any event, the rough agreement seen here between the data in Table 4.1b, Pérez's data, and Falla's data is particularly important because all of these studies were based upon relatively in-depth surveys of small farmers from the same general geographic area, whereas the other yield averages are national averages. Even if the yields contained in Table 4.1b (and the yields found by Pérez and Falla) are slightly high, this would not invalidate their usefulness. The importance of these data is that they suggest how yields respond to different cultivation practices and different technologies. The extreme range of yields found in Table 4.1b suggests that several technologies are currently used in the highlands. This view is supported also by Table 4.5 which presents information on the range of yields found by Pérez.

<u>Examination of the technologies embodied in the activities</u>

The main factors determining milpa yields appear to be: (1) steepness of land which is a rough indicator of soil type and which is measured by the topography dummy (TD); (2) qq of fertilizer used (LBF); (3) distance between rows and between plants (DR and DP); (4) use of an insecticide (ID); and (5) the relative importance of corn versus beans in the output mix. Each activity in Table 4.1b represents a unique mix of these factors. For example, Activity MH1 represents a very low capital technology utilized on quite hilly terrain. Remember that "hillyness" is used here in an attempt to compensate for the lack of information on soil types, and represents poorer quality as well as slope. The labor requirements for milpa are greater on hilly land than on flat or rolling land. This could be due to a variety of factors such as: (1) harder or rockier land is found on hillsides than in valleys; (2) climbing up and down the slope itself requires more energy and hence, slows work; or (3) farmers who must work on poorer soils are poorer and less

Table 4.5. Corn yields on surveyed farms[a]

Number of farmers interviewed in yield/ha range	% of farmers in yield/ha range	Yield/ha range (qq)
32	13	0 - 11.45
73	28	11.45 - 22.90
52	20	22.90 - 34.35
48	19	34.35 - 45.80
27	11	45.80 - 57.25
14	5	57.25 - 68.70
11	4	over 68.70

[a]Pérez, 1971, p. 98.

nourished than farmers on valley land and hence cannot work as fast. It is difficult to know exactly which, if any, of these reasons explains the greater labor requirements for milpa grown on hilly land, and additional research on this would be useful. Nevertheless, the data clearly reveal that farmers on hilly, poorer land work slower.

Activity MH1 in addition to being carried out on hilly land is characterized by no use of fertilizer or insecticide. Hills of corn are planted relatively close together considering that there is no use of fertilizer. MH1 uses very little capital, and has quite low corn and bean yields.

Activity MH2 also takes place on hilly land. Some fertilizer is used, but insecticides are not. Beans are much more important in the output mix than they were in MH1, and the planting density for corn is reduced to allow more room for the interplanting of beans and habas. Bean yields are consequently much higher while the increase in corn yields, although positive, is comparatively small. Note that the increase in corn yields alone is not sufficient to pay for the increased capital used if the corn price is \$3.50/qq. It appears that on hilly land, very low fertilization levels such as depicted here have the primary effect of increasing bean production. Farmers apparently realize this because they plant less corn and allow more room for beans. It would be interesting to know if this is in fact the case, because one wonders what would have happened to yields if planting density of corn had not been decreased.

Activity MV1 is milpa on valley or gently rolling lands. This activity uses very little capital because the costs of seed and depreciation on hoes, sacks, etc. are the only cash expenses. Less seed and less labor are used here than in Activity MH1. Valley soils are more fertile than the hillsides and non-fertilized yields are almost 3 qq/ha higher than they were in MH1. Bean yield is also greater due, perhaps, in part to the better soil and in part to greater spacing between corn hills which allows more room for the interplanting of beans and habas.

Activity MV2 provides the first dramatic increase in corn yields. This takes place on valley land and involves a moderate fertilization level and use of insecticides. Eight out of the nine interviewed farmers who practiced this activity used insecticide. Moderate fertilization allows increased planting density by providing more nutrients. The reduction in planting density places greater emphasis on corn production versus bean production and results in increased corn and decreased bean yields. Insecticide use is an important component of this activity because failure to use insecticides with a high plant density could result in a heavy rootworm population and reduced yields.

Activity MV3 is relatively capital intensive with fertilization being the key ingredient. Only one farmer in this class used insecticide. It may be that insecticide was not needed because rootworms are not a problem in this locality even though planting density is increased. The higher corn yields in MV3 reflect both the increased planting density and the higher fertilization rate. Bean yields are also dramatically higher even though there is comparatively less room for beans. This appears to be a result of the higher fertilization level and is probably a yield in which black beans (that climb up the corn stalks) are more important than habas (which are planted between the hills of corn).

Activity CV2 is corn alone (rather than milpa) on flat or rolling land using a small amount of capital. Here again as fertilizer use declines, planting density also declines (DR and DP increase). A comparison of capital requirements and revenue earned from sale of products per hectare reveals that, with the exception of the demonstration plot results in Activity CV4, the return to land, labor and capital from milpa activities such as MV2 and MV3 is greater than the return from corn alone activities (such as CV2 and CV3). If this is the case, why do farmers grow corn alone? One explanation is that corn alone requires less labor than do milpa activities. The average farm size for farmers who produce corn alone is about 66 cuerdas or approximately 2.9 ha. Earlier work (Johnston, ca. 1973d) with a smaller and simpler linear programming model indicated that the most land a family of four could farm without hiring local labor to assist it in peak labor requiring months was between 2 and 3 ha. It is likely that farmers who have provided data for production of corn alone also grow some milpa and that the amount of milpa grown is inversely correlated with the amount of family labor available and the availability of local hired labor during peak labor requiring seasons.

Activity CV3 represents growing corn alone on flat or rolling land with a fairly high level of fertilization. As a result, corn yields are increased by about 18 qq compared to Activity CV2. Three of the 6 farmers in this group used insecticide suggesting that they are beginning to follow recommendations of their extension agents. Consequently, their yields are improved, but not as much as would be possible.

Activity CV4 is based on a corn demonstration plot run by a Peace Corps volunteer, David Thompson, near Tecpán, Chimaltenango, although the yield used is the average yield for all Peace Corps demonstration plots in 1972 and was provided by Dr. James Walker. These demonstrations show rather dramatically that corn yields for most farmers could be at least doubled if the farmer had the necessary capital and technical knowledge. This activity uses: (1) heavy initial fertilization and a separate application of nitrogen about the time of the first or second cultivation; (2) an insecticide at planting with possible later insecticide applications as needed; (3) greater planting density; and (4) selection of an appropriate variety of native or hybrid corn. This appears to be a rather simple, straightforward formula. As the Rural Development Plan provides more farmers with credit and technical knowledge, further dramatic increases in corn production are expected. It should be stressed that the yields achieved in these demonstration plots are not unseasonably high. Alejandro Barrios, the corn specialist at Labor Ovalle Agricultural Experiment Station, has helped farmers obtain average yields of 114.48 qq/ha, which is only 8.26 qq/ha less than the yield reported by Dr. Walker's Peace Corps demonstration plots. The yield of 122.74 qq/ha which the Peace Corps achieved is, of course, a fine yield compared to national averages, but it is only about 89 bushels per acre. This represents a very respectable, but not an impossible, yield level for farmers to attempt to reach.

The survey results suggest that farmers use more capital intensive technologies on their better land. They may do this because capital is in fairly short supply, or because only farmers with capital can buy good valley land, or because only farmers on good valley land can earn enough to accumulate working capital. Whatever the reason, it is interesting to note that the net return to land, labor and capital from spending about Q54 on flat or better land is approximately Q39/ha higher than a similar expenditure on hilly or poorer lands. As will be shown later, this difference is reflected in higher shadow prices for valley vs. hilly land.

The higher shadow prices for valley land are in a way misleading, because information is not available on yield levels for farmers who use capital intensive technology on hilly, poorer land. This lack of information is unfortunate because one of the major benefits of the Government's agricultural credit and extension program is that it would provide farmers with enough credit so that they could increase yields on hilly lands as well as on valley lands. Activity MH2 demonstrates the effect of using a moderate amount of capital on hilly or poorer terrain. It would be interesting to know the effect of an activity similar to Activity MV3 which is relatively capital intensive, if that activity were carried out on poorer quality lands.

Before leaving corn and milpa activities and going on to potato activities, it is important to point out that the educational process of teaching farmers about the benefits to be gained from use of fertilizers, seeds, insecticides, and increased planting density is already begun. The fact that average corn yields have increased from about 15 qq/ha in the decade of the 1950's to around 23 qq/ha by the later 1960's is evidence that this educational process is already underway. As farmers have more experience with chemical inputs and as credit becomes more accessible to all farmers who need it, further dramatic increases should be recorded in national average corn yields.

Examination of the Potato Activities

Our survey results indicate that potatoes are being produced in three different ways by most farmers in the western highlands. These activities are differentiated primarily by yield, fertilizer use, use of non-fertilizer chemicals, variety and quality of seed (which is represented by price), as well as by quantity of seed (which serves as a proxy variable for planting density). More detailed information on potato activities is contained in Table 4.6b. The fourth activity shown in Table 4.6b consists of a highly technified package of inputs requiring additional capital and providing greater yields. The yield figure given for the fourth activity was obtained from the publication, "Atzimba" Variedad De Papa Para Siembras De Invierno En Guatemala (Schieber et al., 1969), which is based on the results of demonstration trials conducted in 1968 and 1969. Input requirement information for Activity PV4 was provided by P. A. Felipe Dardón, one of the co-authors of the above publication, who is presently the potato specialist at Labor Ovalle Agricultural Experiment Station.

Major constraints facing potato farmers

As can be seen from Column 11 of Table 4.6b, potatoes at a price of Q4.75 per qq have quite high returns to land, labor, and capital. These high returns reflect the fact that potatoes are a specialty crop grown by a small percentage of highland farmers. There are four primary reasons for this.

First, potatoes need much larger amounts of capital than corn, milpa, or wheat. Local experts believe that shortage of capital has been a major constraint for small highland farmers. If so, more potatoes should be produced as the national agricultural loan and technical assistance program administered by DIGESA and BANDESA provides more credit to potato farmers.

Table 4.6a. Definitions of column headings in Table 4.6b

Column no.	Column heads	Definitions of column heads
1	Activity	This refers to a potato production activity or type of technology which was revealed by examination of the sample data.
2	Capital class	This is a grouping of farmers in the sample according to their usage of capital.
3	QQF	The qq of fertilizer applied per hectare.
4	YP	The yield of potatoes in qq/ha.
5	KT	The total amount of capital required.
6	LT	Total labor required.
7	RLL	The return to land, labor, and capital from this activity on one hectare of land assuming a market price of Q4.75 per qq.
8	QQS	The qq of seed required.
9	PS	Price of the seed (Q/qq).
10	IHF	A dummy variable which registers 1 if the farmer used insecticide, herbicide, or fungicide. If he used none of these inputs, it is given a value of 0. A value of 0.85 would indicate that 85% of the farmers in the sample who gave information on the activity used insecticide, herbicide, or fungicide.
11	NFCE	The total value of non-fertilizer chemical expenses.

Table 4.6a. (continued)

Column no.	Column heads	Definitions of column neads
12	STM	The average storage, transportation, and marketing expense incurred by farmers who gave information on this activity.
13	TD	A topography dummy variable. If a farmer responded that he engaged in the activity on hilly or steep land, the topography dummy is given a value of 0. If he farmed flat or rolling land, it is given a value of 1.
14	No. of obs.	The number of farmers in the sample who gave information on this activity.

Table 4.6b. Potato production activities on one hectare of land[a]

(1) Activity	(2) Capital class	(3) QQF	(4) YP	(5) KT	(6) LT	(7) RLL	(8) QQS	(9) PS	(10) IHF	(11) NFCE	(12) STM	(13) TD	(14) No. of obs.
PHV1	1	0.00	45.80	206.06	974	11.49	27.25	5.57	0.00	0.00	45.80	0.50	2
PHV2	2	13.28	233.58	441.23	1436	668.28	37.33	5.57	0.85	24.50	102.13	0.57	7
PHV3	3	15.80	349.91	643.66	1436	1017.96	45.57	6.33	1.00	117.94	102.13	0.44	9
PV4	4	22.90	429.38	723.81	1436	1315.66	45.80	10.00	1.00	112.90	91.60	-[b]	-[b]

[a]Johnston, ca. 1973a.

[b]Results of Ministry of Agriculture potato demonstration trials.

Second, potatoes are a more technical crop in that they require regular fungicide and/or insecticide treatments if a problem begins to develop. Thus, the farmer must be able to diagnose an insect or disease problem early and carry out treatments based on his diagnosis. In short, potatoes require more management skill than do the other traditional crops. As DIGESA's technical assistance activities are increased, more small farmers will develop the requisite management skills. It seems likely, however, that it will take longer and be more difficult to deliver technical assistance to small farmers than to deliver credit.

Third, not all land is equally suitable for potatoes. In general, potatoes do better at high elevations. Different varieties of potatoes respond better to different altitude ranges, but in general, potatoes need altitudes of 2,000 msnm (meters above sea level) or higher. For example, the varieties Tecpán-69 and Tolimán-69 do best between 2,000 and 2,500 msnm; the variety Zaculeu-70 adapts quite well to altitudes of 2,000 to 3,350 msnm; and the variety DIA-71 does best between 2,150 and 2,900 msnm. Most of the land in the study region is between 1,500 and 3,300 msnm. Hence, not all land will be suitable for potato production. In addition to altitude, soil type and water availability from rainfall or irrigation facilities are important factors in successful potato production. Many farmers simply are not fortunate enough to have land with the combination of altitude, rainfall level, and soil type needed for high yields from capital intensive potato production.

Fourth, and perhaps most important, potatoes are a very risky crop. In addition to risk from temperature and rainfall variability there is risk from insect and disease problems, as well as considerable risk due to price fluctuations. Retail August potato prices for Voran potatoes as reported by INDECA (the National Marketing Institute) fluctuated from a low of Q1.93 per qq in 1971 to a high of Q6.09 per qq in 1966. Alpha and Flor Blanca potato prices did not fall as much as Voran prices. Their August, 1971, retail prices were reported as Q2.48 and Q2.05 per qq respectively.

A retail price of Q2.00 per qq probably means that farmers are receiving between Q1.50 and Q1.75 per qq. The effects of fluctuations in farm gate price on the farmer's return to land, labor, and capital are shown in Table 4.7.. Potato Activity PHV3, which is quite a technified potato production activity, will yield a return to land, labor, and capital of Q1,017.96 if the farm gate price is Q4.75 per qq (Q4.75 is regarded as an average price for the past 6 years). If the price falls to Q1.75, the return to land, labor, and capital falls to a negative Q31.32 per hectare. The farmer experiences a net loss. If small farmers are risk averters, one year like 1971 may provide a very strong disincentive for further potato production even though average prices are very favorable (potatoes reportedly sold for as high as Q15.00 per qq in the Central Market of Guatemala City in May and June of 1973).

Table 4.7. The effect of lower prices on the return to land, labor, and capital in potato production Activity PHV3 which has a yield of 349.91 qq/ha and input costs of Q643.66/ha

Price of potatoes (Q)	Return to land, labor, and capital (Q)
4.75	1,017.96
4.50	930.94
4.25	843.46
4.00	755.98
3.75	668.50
3.50	581.03
3.25	493.54
3.00	406.07
2.75	318.59
2.50	231.12
2.25	143.64
2.00	56.16
1.93	31.67
1.75	-31.32

Technification and returns to factors in potato production

Perhaps the most striking aspect of the data in Table 4.6b is the degree of technification used in potato production. Nine of the eighteen farmers interviewed used quite large amounts of capital. The average yield for this group (Activity PHV3) is 349.91 qq/ha which is quite a respectable yield. The fact that some farmers are achieving yields like this points out that much work has already been done with some of the better potato farmers. Column 11 of Table 4.6b shows that these farmers are using fungicides, insecticides, and other non-fertilizer chemical products as needed to ensure that they realize the high yields their new seed varieties are capable of producing. Activity PHV2 is also fairly capital intensive. The yield reported for PHV2 is 233.58 qq/ha which is about 67% of the yield reported in Activity PHV3.

Activities PHV2 and PHV3 both have quite a high return to land, labor and capital when compared to corn, milpa, and wheat activities. Table 4.8 presents the returns to land, labor and capital which may be achieved from all the various crops included in the analysis. Potato Activity PHV2 has a return of Q668.28 per hectare. Potato Activity PHV3 has a return of Q1017.96 per hectare. The return to land, labor, and capital from PHV3 is almost Q770 higher than the return achieved from production of CV4 which has the highest return among the corn alone, milpa, and wheat activities. The return on Potato Activity PHV3 is so high that potato farm gate prices would have to fall as low as Q2.55 per qq (a drop

Table 4.8. Return to land, labor, and capital calculated using the yield information contained in Tables 4.1b, 4.6b, 4.15b and 4.17b with the price information contained in Table 3.9

Crop	Activity	Return to land, labor and savings per ha[a] (Q)
Milpa	MH1	88.45
Milpa	MH2	124.60
Milpa	MV1	112.01
Milpa	MV2	163.44
Milpa	MV3	216.05
Corn alone	CV2	66.59
Corn alone	CV3	88.43
Corn alone	CV4	247.98
Wheat	WHV1	83.65
Wheat	WHV2	84.35
Wheat	WV3	141.69
Wheat	WV4	186.15
Potatoes	PHV1	11.49
Potatoes	PHV2	668.28
Potatoes	PHV3	1017.96
Potatoes	PV4	1315.66
September beets	EB	60.68
October beets	LB	106.25
October green onions	GO	1969.40
September carrots	ECR	631.35
October carrots	LCR	631.35

[a]This is a net return. It is calculated by multiplying the yield per ha for each crop by its average price and subtracting out the value of inputs plus depreciation on fixed capital required to produce one hectare of that crop.

of 46%) before they would reach approximately the same level as the return from CV4.[1] Since potatoes are so profitable, it is likely that average potato prices will decline as more farmers have access to credit and technical assistance. Based on the relative returns to land, labor, and capital shown in Table 4.8, it would not be surprising to see average potato prices fall to Q3.00 per qq or lower over the next few years.

<u>Potato yields</u>

The profitability of potatoes is due partly to favorable market prices and partly to high yields (Table 4.6b). The effect of declining prices on a semi-technified potato production activity is shown in Table 4.7. Declining yields would have a similar effect. Yields are not expected to decline, but one may still ask, "How reasonable are the yields presented in Table 4.6b?" This is a difficult question to answer, because the yield estimates reported by different sources show substantial variation.

Table 4.9 contains chronological information on potato yields from several sources for the period 1964-1973 that can be used to evaluate the reasonableness of our survey yields. Table 4.9 consists of four sets of yield estimates. The first set is composed of studies carried out between 1964 and 1968; these studies are

[1]This comparison is only approximate because PHV3 requires Q486.60 more cash for input costs than does CV4, and the interest cost associated with borrowing this capital is not netted out. Nevertheless, the comparison demonstrates the rather extreme profitability of potatoes when grown in a semi-technified manner such as Potato Activity PHV3.

Table 4.9. Potato yield information as reported by various sources

Study no.	Year	Source	Yield (qq/ha)	Additional information
1	1964	Pérez[a]	133.96	Pérez cites the publication, Estadisticas Mundiales de Cultivos, FAO, June, 1966.
2	1966	Schmidt[b]	250.0	
3	1968	Walker[c]	85.5	This is a national average estimate.
4	1968	Gollas[d]	134.0	Gollas' sample included 42 farmers who grew potatoes. Total land area devoted to potatoes by all 42 was 5.9 ha.
5	1968	Gollas[d]	197.0	If the farmers from Totonicapan are excluded, the average yield is 197 qq/ha.
6	1969	Pérez[a]	274.78	The sample contained only 12 farmers. Ten were from Almolonga, 1 was from Totonicapan, and 1 was from Quiché. The total land area cultivated by all 12 was 0.42 ha.

[a]Pérez, 1971, p. 111.

[b]Schmidt, 1969, p. 45.

[c]Walker, 1968.

[d]Gollas, 1970, pp. 26-28.

Table 4.9. (continued)

Study no.	Year	Source	Yield (qq/ha)	Additional information
7	1969	Schieber[e]	429.38	This yield was attained on demonstration plots using the variety, Atzimba, at altitudes between 1800 and 2150 msnm.
8	1972	Palencia[f]	646.75	Results of lower yielding trials using the variety Atzimba at lower altitudes.
9	1972	Palencia[f]	727.52	Results of higher yielding trials using the variety Atzimba at higher altitudes.
10	1972	Dardón[g] and Espinoza	572.46	Results of demonstration trials using the varieties Tecpán-69, Zaculeu-70, and DIA-71 at appropriate altitudes.
11	1973	Johnston[h]	349.91	The nine farmers with the most capital intensive production averaged this yield. Another group of seven averaged 233.58 qq/ha. Two other farmers averaged 45.80 qq/ha.

[e]Schieber, Dardón, and Velásquez, 1969.

[f]Palencia _et al_., 1973.

[g]Dardón and Espinoza, _ca_. 1972 or 1973.

[h]Johnston, _ca_. 1973a.

numbers 1-5. The average yield for the first four studies (the 5th is a subset of the fourth) is 150.87 qq/ha which is probably a reasonable figure for the 1964-1968 period. Note however that this set of yields has a range of 164.5 qq. This illustrates the yield impact of different soil and climatic conditions as well as the effect of management practices. Gollas' data clearly illustrate this (observation numbers 4 and 5 of Table 4.9). The average yield including farmers from the Department of Totonicapan was 134 qq/ha while the average yield excluding them was 197 qq/ha. Although it is difficult to draw precise inferences from data with such a wide range of observations, it is probably reasonable to conclude that most of the better farmers in these studies were achieving yields of between 150-250 qq/ha during 1964-1968. Study Number 6 is based on data for 12 farmers, 10 of whom were from Almolonga. Farmers in Almolonga are among the better farmers in the highlands. Pérez's data indicate that in 1969, these farmers had average yields of about 275 qq/ha. Studies 7, 8, 9, and 10 are based on field trials which were usually conducted in cooperation with a local farmer. Most of these trials would have been conducted between 1968 and 1972. The average yield for these studies (each of which is itself an average of a number of trials) is 594 qq/ha, more than 100% higher than the average yield in Pérez's 1969 study. The rather spectacular difference between yields achieved by farmers in Almolonga and demonstration plot results conducted at about the same time is probably due to three major factors. First, even the better farmers may face shortages of capital, time, or other resources which impede them from using all the technical inputs they have knowledge of. Second, the farmer may simply not have the technical expertise which would allow him to duplicate production levels achieved by farmers working with agronomists in field trials. Third, it was during this period that new high yield varieties were being imported from Mexico. The agronomists were introducing these high yield varieties in their field trials and choosing those varieties that were most appropriate for potato areas in Guatemala. Even if farmers knew about the new varieties and had money to buy the seed, they might not have been able to buy them because they were still in the process of being introduced and adapted; only limited amounts of seed were available for commercial production. Consequently, field trial results showing potential production levels were far above actual production levels because most producers did not have access to these new varieties.

Study Number 11 is based on data from better farmers in 1973. The average yield of 349.9 qq/ha is 75 qq/ha higher than the yields reported by Pérez in 1969 and 79 qq/ha lower than the demonstration plot results reported by Schieber in 1969. This suggests that farmers may be beginning to use the new varieties. If the data in Study 11 is approximately correct, in four years farmers have been able to reduce the gap between potential and actual yields as measured by Schieber's and Pérez's data by 50%. During these four years, however, field trial yields have increased by over 100 qq/ha. As agronomists become more successful in determining which varieties are most appropriate for each region, and as the new varieties become more available, it seems likely that average yields of better farmers will reach the 429.38 qq/ha which Schieber reported as a possible yield in 1969. The latest field trials conducted by Walker and Dardón suggest that even higher yields could be attained.

Potato Activities PHV1, PHV2, PHV3, and PV4

The potato yields which have been, are being, and probably will be attained have been discussed at some length. Now let us move to a more specific discussion of each of the four potato production activities presented in Table 4.6b.

Activity PHV1 represents a very traditional production activity. No fertilizer or other agricultural chemical is used. The seed is probably selected from last year's production or bought at a local market. The return to land, labor, and capital is the lowest of any of the crop activities considered in the analysis. Planting density is quite low; PHV1 uses only 49% as much seed as is recommended in Activity PV4. This type of activity is probably carried on by farmers who want to grow a few potatoes for their own consumption. It is doubtful that many farmers engage in Activity PHV1 as a commercial venture. There is only one reasonable explanation why a farmer might produce potatoes commercially using an activity such as PHV1. If the farmer has difficulty in hiring 4th quarter local labor, he may put part of his land into potatoes because potatoes require no 4th quarter labor. He would do this only if he had extra land and access to potato seed but no money for fertilizer and could not hire 4th quarter labor. Labor requirements for potatoes and corn, milpa, or wheat production are very complementary. This rather tenuous line of reasoning could explain why some farmers might engage in an activity which does not appear to be very productive in comparison with the other cropping activities included in this study, but it is more likely that Activity PHV1 involves only subsistence or home consumption production.

Activity PHV2 definitely represents commercial production. Yield is less than one-half the possible yield levels reported by Walker and Dardón in Table 4.9, but is nonetheless respectable. The average seed potato price reported in Column 13 of Table 4.6b indicates that these farmers have not begun to purchase the new varieties of seed potatoes which are used in demonstration trials. Fertilizer is being used. These farmers averaged 13.28 qq of fertilizer per ha which is 58% of the amount recommended by extension agents as specified in Activity PV4. As in the case of corn, use of fertilizer is accompanied by increased planting density. Activity PHV2 uses 10.08 qq more seed potatoes than did Activity PHV1. Use of fertilizer allowing increased density of planting is a good example of the type of capital land substitution which is needed in an area like the highlands in which land is almost a fixed factor and is in relatively short supply. This group of farmers uses some non-fertilizer chemical inputs, but their use of these inputs is only minimal. Farmers practicing Activity PHV2 spend only 21% of the amount recommended in Activity PV4 for non-fertilizer chemicals.

Activity PHV3 represents the highest level of technology, the highest yields and the highest use of capital of the farmers interviewed in 1973. Fertilizer usage is about 70% of the level recommended for demonstration plots. Planting density has increased and an additional 8.24 qq/ha of seed potatoes are needed in Activity PHV3. Average seed price has increased by Q0.76 per qq over seed prices paid by farmers using Activities PHV1 or PHV2. Most of these farmers are probably not buying certified seed such as is used in Activity PV4 and which costs Q10.00 per qq, but instead are buying seed potatoes from someone who planted certified seed the year before. Thus, they are getting 2nd generation certified seed and are paying more for it than for traditional seed, but are also probably receiving some of the benefits accruing to use of the new varieties. It is difficult to know if they buy the second generation seed due to a shortage of capital or a shortage of certified seed. Probably both of these factors are important. Average use of non-fertilizer chemicals reported by this group was Q5.04 higher than the use recommended in Activity PV4. These farmers have come a long way toward learning how to use technified potato production input packages.

Activity PV4 represents a set of inputs recommended by Philipe Dardón, potato specialist at Labor Ovalle Agricultural Experiment Station, for use in the field to achieve the yield levels produced in demonstration plots. The only significant difference between this activity and Activity PHV3 is in usage of fertilizer and certified seed. Activity PV4 used 7.1 more qq of fertilizer per ha and pays Q3.67 more per qq for certified seed. The return to land, labor, and capital from Activity PV4 is Q1315.56 per ha. This is a very attractive production activity at 1973 prices. As farmers gain access to credit and technical assistance, some farmers should surpass the PV4 yield. Demonstration plot results are currently achieving yields of 600 and 700 qq/ha; from 170 to 270 qq/ha higher than the yield used in PV4. It is likely that as more farmers adopt production activities similar to Activity PV4, the supply of potatoes will be increased and average potato prices will begin to decline, probably within the next 3-5 years.

Wheat Activities

Four wheat growing activities are identified in this study. They are distinguished principally by yield, total Quetzales capital required, fertilizer used, herbicide usage, degree of mechanization, and topography. Again, it is assumed that the topography dummy variable represents a crude proxy for land fertility or quality. This assumption allows us to identify two classes of land, and provides a more reasonable estimate of the resources available to the farmer. Although topography is only one of several factors affecting soil quality, the use of the topography variable to distinguish soil classes seems preferable to the alternate assumption that land on flat farms is identical to land on steeply sloped farms.

Gremial Nacional de Trigueros

Wheat is the most highly technified of the traditional crops included in this study. The adoption of new technologies and new wheat varieties by highland farmers has been successfully promoted by both the Ministry of Agriculture staff and the Gremial Nacional de Trigueros (the National Wheat Growers Association). The Gremial Nacional de Trigueros was formed in 1958 (Fletcher et al., 1970) by the Asociación Nacional de Productores de Harina (the National Miller's Association) to promote production of wheat and to assure that at least 30% of the wheat consumed in Guatemala is procuced domestically. Table 4.10 contains information on estimated wheat yields from 1950 to 1968. Much of the improvement in yields shown in Table 4.10 after 1958 is attributable, at least in part, to the efforts of the Gremial. The Gremial has introduced new wheat varieties, provided seed and fertilizer credit (in kind), and has conducted yield and fertilizer demonstration trials. In addition, the Gremial and the Asociación have worked together to assure farmers a reasonable price for their wheat. There has been some criticism that individual mill owners have upon occasion paid less for their wheat than the official support price of Q6.00/qq which

Table 4.10. Wheat yield estimates 1950-1968[a]

Year	Yield (qq/ha)	Average yield for preceding years (qq/ha)
1950-51	12.89	
1951-52	13.62	
1952-53	13.44	
1953-54	12.37	
1954-55	12.03	
1950-55		12.87
1955-56	9.32	
1956-57	12.59	
1957-58	12.02	
1958-59	14.07	
1959-60	13.83	
1955-60		12.37
1960-61	14.79	
1961-62	15.94	
1962-63	17.83	
1963-64		
1964-65	27.14	
1960-65		18.93
1965-66	20.13	
1966-67	20.83	
1967-68	20.15	
1965-68		20.37

[a]Juarez, P., *et al.*, *ca.* 1969.

was established by law in 1954. Pérez reported that in 1969 farmers were receiving prices of from Q5.50 to Q5.95/qq (Pérez, 1971). Field surveys in 1973 showed that the average price received by farmers was Q5.71/qq (Johnston, ca. 1973a). The difference between actual farm gate prices and the official support price is difficult to calculate, however, because of the way in which the millers and the farmers interact at harvest time. Frequently, the miller brings a threshing machine to a location near the farm. The farmer carries his wheat (on the stem) to the thresher and immediately sells his threshed grain to the miller. Thus, the miller performs threshing, transportation and some storage services for the farmer. Probably at least a part of the discrepancy between prices reported by farmers and the official support price of Q6.00/qq reflects charges for these services. Although there may be some monopsonistic exploitation of the small farmers by millers, it is difficult to quantify the extent of such exploitation.

Degree of technification and mechanization

Wheat farmers, as a group, have already accepted fertilizer use, and many of them are using other agricultural chemicals such as herbicides and, to a lesser extent, insecticides. In addition, a good deal of mechanization is being used by the larger landowners and also by smaller landowners on a custom hire basis. Wherever the land is flat enough to allow use of tractors and combines, they are being introduced.

Wheat specialists at Labor Ovalle Experiment Station report that larger landowners have been moving toward mechanized cultivation for quite some time, and that demand for mechanized custom hire services from smaller farmers is increasing as well. Small farmers with relatively flat small plots of good wheat land will often request a larger farmer with mechanized equipment to do custom hire work for the whole group. Sometimes this involves only land preparation or only combining, but in a few instances the entire operation is mechanized. The small farmers acquire seed, fertilizer, and herbicide from the Gremial. The mechanized farmer takes these inputs and then plows, disks, plants, applies herbicide, and harvests. The group of small landowners does nothing but apply for inputs and sell the grain. Relatively small landowners (those with only 2 or 3 ha or less) often find this to be a good arrangement if they face a shortage of family labor during a peak labor requiring time such as 4th quarter. This labor shortage occurs because corn, in particular (and wheat to a lesser extent), requires relatively larger amounts of labor in the 4th quarter. By custom hiring part or all of the wheat production work on one small parcel of their land, they are able to free labor resources and farm their remaining land more effectively.

Capital labor substitution

Wheat appears to be the only traditional crop in which any substantial degree of mechanization is being introduced by small farmers in order to save labor during peak labor requirement periods.

As mentioned earlier, an initial study of traditional agriculture using a smaller linear programming model (Johnston, 1973d) showed that a farmer with two or more hectares faced seasonal shortages of family labor if he wanted to grow only milpa which was his most profitable alternative in that model. This paper explained that an observed shift from milpa to potatoes allowed increased sale of migratory labor and was motivated primarily by the shortage of 4th quarter family labor in that model. Also, as mentioned previously, farmers may grow corn alone (which usually has a lower return to land, labor, and capital than milpa) because corn alone requires less labor than milpa.

The shortage of family labor on a seasonal basis which is indicated by these findings will be serious only if there is also a shortage of hired agricultural labor during the same periods. It was not possible to carry out a detailed analysis of seasonal labor demand and supply at a local or regional level. Consequently, it has not been possible to investigate the seriousness of a family labor shortage, and one can only note that there is an observable trend toward increased mechanization in wheat production. This trend is probably attributable to two factors. First, there appears to be a shortage of family labor on farms of over 2 ha during certain times of the year. Farmers are being given the option of filling this shortage by hiring local labor or by custom hiring mechanized equipment. The fact that farmers are moving toward increased use of mechanized equipment indicates that in some areas there is a seasonal scarcity of local hired labor given the prevailing wage rates for agricultural labor in the highlands. A second important factor contributing to the observed trend toward increased mechanization is that wheat today is a much less risky and more profitable crop than any of the other traditional crops. The availability of improved seeds, fertilizer, and herbicides through the Gremial combined with the fact that farmers can count on receiving a price of from Q5.50 to Q6.00/qq for their grain means that they can afford to bear the risk of moving away from traditional production methods. Hence, the move toward mechanization may simply be an outgrowth of the acceptance of newer technologies.

If the above observations are valid, we can expect to see selective mechanization taking place not only in wheat production, but among all the traditional crops in the future. Mechanization has occurred first in wheat production because wheat is a crop which is comparatively risk free, and because wheat is a comparatively simple crop which lends itself well to mechanized production. The farmer plows, disks, seeds, fertilizes, applies herbicide, and harvests. All these operations are easily mechanized. Plowing, disking, seeding, fertilizing, and application of herbicide can almost all be done at once with perhaps two or three passes across the field. Harvesting is, of course, done later, but it too comes at a time of the year when the farmer with two or more hectares may be quite busy.

It is unlikely that milpa or potato production will become as highly mechanized as wheat. Credit for milpa and potatoes will probably never be quite as readily accessible to small farmers as is wheat credit, nor will these crops be as risk free or as easily mechanized as wheat. Milpa would be particularly difficult to mechanize because of the interplanting. Potatoes would be difficult to mechanize because they are often grown on very small plots, frequently on steep terrain. It seems doubtful that mechanization would be needed on very small plots, or that farmers could afford to allow someone else to decide when and how much insecticide or fungicide should be applied because timeliness of application is much more important for potatoes than for wheat. Nevertheless, there may be some tasks in corn, milpa, and potato production which could and should be mechanized, seedbed preparation might be an example. At present, the Government does not really have a mechanization policy. Parts for agricultural machinery are heavily taxed which acts as a disincentive to mechanization, but this tax policy probably was not chosen for this purpose.

Historical trends in wheat yields

Wheat yields, like corn and potato yields, have been increasing. The wheat yields in Table 4.11 show rather wide variations for the same year depending upon: (1) who is doing the reporting, and (2) more important, who they are reporting on. These yield reports are essentially from three different groups. Observations 1, 2, 5, 6, 7, 10, and 18 are estimates of average yields for more or less average

Table 4.11. Historical wheat yields

Obs.	Year(s)	Reported yield (qq/ha)	Source	Additional information
1	1950-60	12.62	Planning Council[a]	See Table 4.10 for yearly estimates
2	1960-65	18.93	Planning Council[a]	See Table 4.10 for yearly estimates
3	1964-65	28.63	Wheat Growers Union[b]	Average yield for 7 highland departments
4	1965-66	31.60	Wheat Growers Union[b]	Average yield for 7 highland departments. Yield for Chimaltenango was 65.49 and the yield for San Marcos was 19.47
5	1965-68	20.37	Planning Council[a]	See Table 4.10 for yearly estimates
6	1967-68	23.0	Gollas[c]	Average highland department yield
7	1968	27.14-31.46	Pérez[d]	Based on 45 observations in the Departments of Sololá, Totonicapan and San Marcos

[a]Juarez Pérez et al., ca. 1969.

[b]Gremial, 1967.

[c]Gollas, 1970.

[d]Pérez, 1971.

Table 4.11. (continued)

Obs.	Year(s)	Reported yield (qq/ha)	Source	Additional information
8	1968	85.86	Labor Ovalle Report[e]	Yield trial results using the variety Nariño
9	1968	93.02	Labor Ovalle Report[e]	Yield trial results using the variety Xelaju-66
10	1968	17.0	Walker[f]	
11	1968-69	57.24-68.29	Labor Ovalle Report[e]	Yield trial results using the variety San Andres-68
12	1969	45.79	Labor Ovalle Report[e]	Yield trial results using the variety Tobari-66
13	ca. 1969[f]	60.10	COMPACO[g]	Yield estimates for farmers using the variety Nariño as part of a capital intensive input package
14	ca. 1969[f]	40.07	COMPACO[g]	Yield estimates for farmers using the variety Lerma Rojo as part of a capital intensive input package

[e]Cruz, 1973.

[f]Walker, 1968.

[g]COMPACO, ca. 1969.

Table 4.11. (continued)

Obs.	Year(s)	Reported yield (qq/ha)	Source	Additional information
15	ca. 1969[f]	42.93	COMPACO[g]	An average yield estimate for farmers using an appropriate variety for their region as part of a capital intensive input package
16	1972	33.07	Palencia[h]	Low yielding trials (drought)
17	1972	68.34	Palencia[h]	High yielding trials
18	1973	34.34	Johnston[i]	Weighted average of yields in Table 4.15b
19	1973	67.78	Johnston[i]	Activity 4 of Table 4.15b

[h]Palencia et al., 1973.

[i]Johnston, ca. 1973a.

farmers. These observations show a rather steady upward trend in yields from 1950 to 1973 (Table 4.12). Although these estimates are probably a little above or below the actual national average, they are descriptive of the trend in yields which is taking place.

Observations 3, 4, and 15 appear to be yield estimates for "better than average" farmers. Observations 3 and 4 were made by

Table 4.12. Yield estimates for "average" farmers[a]

Obs.	Year(s)	Yield (qq/ha)	Source
1	1950-60	12.62	Planning Council
2	1960-65	18.93	Planning Council
5	1965-68	20.37	Planning Council
6	1967-68	23.00	Gollas
7	1968	27.14-31.46	Pérez
10	1968	17.00	Walker
18	1973	34.34	Johnston

[a]Data taken from Table 4.11.

the Gremial and are presumably representative of the more progressive farmers who are members of the Gremial. Observation 15 represents an estimate of the average yield which can be attained if farmers use an appropriate variety and a relatively capital intensive input package. Table 4.13 presents the yield trend being experienced by these "better" farmers.

Observations 8, 9, 11, 12, 13, 14, 16, 17, and 19 are yields achieved on demonstration plots and in experiment station trials. They provide important information for this study for two reasons. First they show the direction, and to a certain extent provide

Table 4.13. Yield estimates for "better" farmers[a]

Obs.	Year(s)	Yield (qq/ha)	Source
3	1964-65	28.63	Wheat Growers Union
4	1965-66	31.60	Wheat Growers Union
15	ca. 1969	42.93	COMPACO

[a]Data taken from Table 4.11.

estimates, of yields which better farmers will be achieving in the future. Second, the extreme variability of these figures show the importance of finding the appropriate variety of wheat for a specific region. To achieve top yields a variety must be right climatically, geographically, and disease-wise. While one can breed quite successfully for climate and geography and achieve relatively lasting results, this is difficult to achieve for some types of disease resistance, especially for the class of funguses commonly known as wheat rust. At least 275 distinct physiological races or biotypes of the stem-rust organism have been discovered, but only a few of these are of economic importance at any one time in a region (Martin and Leonard, 1967). In addition to stem-rust wheat may also be attacked by the less virulent leaf rusts and/or stripe rusts. Rust is a particularly serious disease problem because the funguses which cause rust in a given region or environment may mutate or, as the rust reproduces, there may be a sexual recombination of rust genotypes. This can result in the introduction of a new variety of rust which may be successful in attacking the bred-in resistance which the wheat had to the original varieties of rust. Consequently, a variety of wheat which did very well in a particular valley in 1965 may not do nearly as well in 1970 because that variety's resistance to the original local strains of rust may no longer be adequate. This means that breeders must continually develop new wheat strains for the same region. Although it is occasionally possible to transfer the original variety of wheat to another valley where the local rusts cannot attack it, this is not always possible. A wheat variety that does very well in Chimaltenango may not be suitable for Huehuetenango or Quezaltenango, because the performance of a variety is often quite sensitive to relatively minor altitude or temperature changes. In Guatemala climates can vary from tropical to temperate in a distance of 20 miles with climatic pockets representing all gradations in between. It therefore is often difficult to transfer a successful variety in one valley to another valley, because there usually are small climatic variations between valleys which may affect yields for a particular wheat strain.

The yield variability for demonstration plots are extremely wide even though attempts are made to select appropriate varieties and farmers presumably use capital intensive input packages. These observations are presented in Table 4.14. While it is difficult to

Table 4.14. Yield estimates from demonstration plots[a]

Obs.	Year(s)	Yield (qq/ha)	Variety	Source
8	1968	85.86	Nariño	Labor Ovalle Report
9	1968	93.02	Xelaju-66	Labor Ovalle Report
11	1968-69	57.24-68.29	San Andres-68	Labor Ovalle Report
12	1969	45.79	Tobari-66	Labor Ovalle Report
13	_ca._ 1969	60.10	Nariño	COMPACO
14	_ca._ 1969	40.07	Lerma Rojo	COMPACO
16	1972	33.07 (drought)	unspecified	Palencia
17	1972	68.34	unspecified	Palencia
19	1973	67.78	unspecified	Johnston

[a]Data taken from Table 4.11.

say anything definite about future yields where the range is as wide as the one in Table 4.14, it would appear that better farmers with the correct variety could achieve yields of from 65-70 qq/ha. Whether or not _average_ yields will eventually reach this level is another thing. Judging from the range of yields shown in Table 4.14, it appears unlikely that _average_ yields will rise above 35-45 qq/ha in the near future.

Wheat production activities used in the analysis

As was mentioned earlier, the work of the Gremial Nacional de Trigueros, the Asociación Nacional de Productores de Harina, and the Ministry of Agriculture has resulted in increased use of chemical inputs and improved yields over the past 15 years. The results of this effort are reflected in the usage levels of agricultural chemicals reported in the four wheat production activities of Table 4.15b.

Activity WHV1, the least capital and chemical intensive technology presented, has an average fertilizer use level of 6.18 qq/ha as reported by the 11 farmers who provided data for this activity. This is in contrast to our findings for milpa, corn, and potatoes where there was always one group of farmers who used no fertilizer. The higher level of fertilizer use in wheat production is almost surely attributable to the incentives provided by the guaranteed price paid by the millers (which is, of course, required by law) and the provision of credit in kind by the Gremial.

Fertilizer is the only agricultural chemical used by farmers in Activity WHV1. Activity WHV1 uses no mechanization, no herbicide, or insecticide and almost no urea (one farmer out of 11 used urea). Consequently, this is a relatively more labor intensive technology than any of the other activities. Column 5 of Table 4.15b shows that labor requirements decrease as production activities become more technified. It is important to keep this in mind. There is a rather large difference in labor requirements for Activity WHV1

Table 4.15a. Definition of column heads in Table 4.15b

Column no.	Column heads	Definition of column heads
1	Activity	Identification number for the wheat production activity.
2	QQF	The qq of fertilizer used per hectare.
3	YW	The yield of wheat in qq/ha.
4	KT	Total amount of capital required (Q) per hectare.
5	LT	Total number of labor hours required per hectare
6	HD	A dummy variable for herbicide use. A value of 1 means that all of the farmers who performed this activity said that they used a herbicide. A value of 0.5 means that half of the interviewed farmers used a herbicide.
7	ID	An insecticide dummy variable. A value of 1 signifies that 100% of the farmers in this activity class used an insecticide.
8	UD	A urea application dummy variable. A value of 1 signifies that 100% of the farmers in this activity class applied urea.
9	TD	A topography dummy variable. A value of 1 means that 100% of the farmers interviewed in this class farmed land that was flat or gently rolling as opposed to a value of 0 which stands for hilly or very steep slopes. Slope is believed to be a crude proxy variable for quality with most of the better

Table 4.15a. (continued)

Column no.	Column heads	Definition of column heads
		lands being found in valleys and hence, having a topography dummy of 1.
10	MLPD	A dummy variable for the use of machinery to prepare land for planting. A value of 1 signifies that 100% of the farmers used machinery to prepare their land.
11	MHD	A mechanized harvest dummy variable. A value of 1 signifies that 100% of the farmers in this activity used some type of mechanization in the harvest process.
12	GTD	A general technology dummy variable. This variable measures the degree to which the farmer uses mechanical and chemical inputs in wheat production. It has a possible range of from 0-8.
13	RLL	The return to land, labor, and capital from growing wheat with this activity (technology) on 1 ha of land. This is a net return with the cost of seed, chemical, and mechanical inputs being subtracted out.
14	TC	The total land area owned by the farmer measured in cuerdas. One cuerda = 0.04 ha.
15	QQS	The qq of seed needed for one hectare.
16	PS	The price of 1 qq of seed measured in Quetzales.
17	No. of obs.	The number of farmers interviewed whose production practices put them in this activity class.

Table 4.15b. Wheat production activities on 1 ha of land[a]

(1) Activity	(2) QQF	(3) YW	(4) KT	(5) LT	(6) HD	(7) ID	(8) UD	(9) TD	(10) MLPD	(11) MHD	(12) GTD	(13) RLL	(14) TC	(15) QQS	(16) PS	(17) No. of obs.
WHV1	6.18	28.17	78.33	1006	0	0	0.1	0.45	0	0	1.0	83.65	35.18	4.12	7.45	11
WHV2	7.79	30.92	93.44	721	1	0	0.9	0.30	0	0.5	3.6	84.35	29.80	3.32	8.40	10
WV3	10.53	46.03	122.98	538	1	0	0.3	1.00	1	0.3	4.7	141.69	14.33	5.95	5.33	3
WV4	12.60	67.78	203.59	538	1	1	1.0	1.00	1	1.0	8.0	186.15	48.50	7.10	8.50	2

[a] Johnston, _ca_. 1973a.

as opposed to the other three activities, and this difference is primarily a reflection of the capital labor substitution that has taken place in the other three activities. Column 13 of Table 4.15b shows the return to land, labor, and capital in wheat production. One must exercise some caution in the interpretation of Column 13. It shows that the return to land, labor, and capital for Activities WHV1 and WHV2 are almost equal. This is because neither the charge for hiring the additional labor needed by WHV1 nor the interest charge for borrowing the additional capital needed for WHV2 is included in this calculation. The three hundred additional labor hours required by WHV1 would cost a farmer about Q22.50 at 7.5¢/hr. The fifteen Quetzales extra capital required by Activity 2 would cost Q1.50 if borrowed at an interest rate of 10%. Thus, the return to land (and to the farmer who in this case farms his own land) is Q21.00 higher if the farmer uses Activity WHV2. This is not readily apparent if one makes only a casual examination of Column 13. Activity WHV1 appears to use a variety of seed which is not of the highest quality because its price is only Q7.45/qq as opposed to the price of Q8.50/qq which is paid for seed in Activity WV4. Column 9 (TD) tells us that this activity is typically carried out on both hilly and valley lands.

Activity WHV2 is also an activity which is found on both hilly and valley lands. Wheat yields here are increased by 2.75 qq/ha over Activity WHV1 and use of fertilizer is increased by 1.61 qq/ha. All of the farmers who responded to Activity WHV2 used herbicides and 1/2 of them used some type of mechanical aid for harvesting. In most cases this is limited to use of a mechanical thresher to remove grain from the stem. Farmers using Activity WHV2 are using urea in addition to a balanced fertilizer and therefore are probably making two fertilizer applications. This suggests that they are adopting the recommendations of extension agents and others who are trying to teach them about new higher yield technologies. The average seed price of Q8.40/qq shown for this group indicates that they are buying quality seed. It appears that they may not be planting as densely as they should because they report using only 3.32 qq of seed per ha. This relatively light use of seed might be due in part to the custom of making small terraces with one or two rows of seed per terrace on hilly lands. It is probably also explained in part by the observation that the fertilization level used here is also quite low. Compared to Activity WV4, these farmers use 62% as much fertilizer and 39% as much seed. Farmers may not be receiving as much fertilizer as is recommended in Activity WV4 or they may be receiving it but not using it all on wheat. If farmers are taking part of the fertilizer given to them by the Gremial for wheat production and using it on corn or potatoes, then there would not be much point in using the recommended amount of seed, which might explain the relatively light seed use found in Activity WHV2.

Activity WV3 appears to represent a new technology (but might in part be the result of farming in a fortunate climatic zone).

There are only 3 observations for this activity, yet the yield given in Column 3 and the general technology dummy variable found in Column 12 indicate that these activities are distinct from Activities WHV2 and WV4. Fertilizer use represents an intermediate step between Activities WHV2 and WV4 as does yield, planting density (QQS), return to land, labor, and capital, and the general technology dummy. These farmers use herbicide, but only one of three used urea. Their seed price is relatively low indicating that they are not buying certified seed. Activity WV3 takes place on valley land, and all three farmers used custom hired services for land preparation. As a result of using custom hire land preparation services, herbicides and some mechanical harvest help, total labor requirements decrease by 183 hours as compared to Activity WHV2. There might also have been some reduction in labor required because this activity takes place on valley land while Activity WHV2 was found on both hilly and valley land. The high yield of 46.03 qq/ha for Activity WV3 indicates that these farmers are either better or more fortunate than many farmers.

Activity WV4 is the most technological and capital intensive of the activities considered. One observation which provided data for this activity came from a fertilizer demonstration plot being conducted by the Ministry of Agriculture and the Peace Corps. The other observation came from a farmer interviewed in our sample. Activity WV4 uses 2.07 qq more fertilizer than did Activity WV3. It uses herbicide, insecticide, urea, and (probably) certified seed.

Planting density is the highest of any of the activities considered. The farmer who engaged in Activity WV4 used mechanization to assist him in land preparation and at harvest time even though his total land holdings were only 48.50 cuerdas or approximately 2.12 ha. The average yield for these two observations of 67.78 qq/ha is very respectable. It is not as high as some of the yields reported in Table 4.14, but it is a reasonable yield expectation for better farmers using certified seeds in favorable climatic zones. Activity WV4, like Activity WV3, takes place exclusively on valley land.

Hill and Valley Yields

One of the more interesting findings of the sample data for milpa, corn, potatoes, and wheat has been that the most capital intensive production has in each case taken place on valley lands. There are a variety of factors which might explain this finding. First, as was stated earlier, the yield levels in the sample data suggest that hilly land is often poorer land in Guatemala. Although hilliness is a poor proxy for fertility, slope is the only available variable that provides some information on variations in soil quality. Second, most of the larger towns are located in valleys. This means that the valley farmer has greater access to transportation facilities, technical assistance from Ministry of Agriculture personnel, education, information supplied by merchants selling agricultural chemicals, and credit which is usually available in departmental capitals located in the valleys. Third, valley soils are usually not as subject to erosion as are hillside soils. Thus there is less chance on valley soils that rains will wash fertilizer and other chemicals downhill and away from the plants. Consequently, if farmers fertilize only a part of their land, they are probably better off to use their fertilizer on valley lands. This appears to hold true for wheat, corn, milpa and potatoes.

Vegetable Production

Vegetable production has been included here to provide information on the relative profitability of vegetable production on good nonirrigated land as opposed to traditional crop production. To this end the analysis considers production of only three vegetables which require a minimum of water if grown during the rainy season. Although some irrigation might be needed in the seedbed (or during the first two or three weeks for carrot production), by the time of transplanting, rainfall levels should be sufficient to provide 95-100% of the water required. Since vegetables are more sensitive to water requirements than are many field crops, it is necessary to differentiate vegetable land from other land. This was done by assuming that the farmer has only one cuerda of land upon which he can grow vegetables. The one cuerda limit is imposed because the farmer is assumed to be primarily a producer of traditional crops. This is nonirrigated land, but is located relatively close to a water supply during the rainy season (during the dry season this water supply is assumed to disappear). Labor requirements in the model are increased because the farmer may occasionally have to hand carry water to his vegetables.

It is important to emphasize that this production is not taking place on irrigated land. If it were, then the farmer could grow a much larger variety of vegetables than the three selected, and he could grow three or four crops per year instead of one. The land used for vegetable production is similar to the better land used for traditional crops, but it is not typical land, because it must be located within a few hundred yards of a water source. This would be especially important at transplanting time, but might also be important during the "finicula" or the short dry period which usually occurs for the space of five to fifteen days in the middle of the rainy season.

Readers familiar with Guatemala can consider this activity as being similar to rainy season production of onions grown on mountain slopes near Zunil, or beet and carrot production on nonirrigated land in the Departments of Guatemala and Chimaltenango. Most vegetable production in Guatemala is, of course, done on irrigated land, but a look at monthly average wholesale prices as published by INDECA suggests that additional land is being put into production of some vegetables during the rainy season. Table 4.16 presents information on monthly wholesale prices which shows that prices fall during August, September, and October, the months when most nonirrigated vegetables would be marketed. The exact month in which the farmer would have vegetables ready for market

Table 4.16. Average monthly prices for three vegetables, 1966-71[a]

Month	Medium green onions[b]	Carrots[c]	Beets[c]
January	7.99	2.17	1.95
February	7.38	2.12	2.00
March	7.59	2.03	2.09
April	6.39	1.69	2.01
May	6.46	1.96	1.98
June	6.78	1.94	2.06
July	8.06	1.88	1.98
August	6.24	2.19	1.90
September	6.30	2.20[d]	1.64[d]
October	7.56[d]	2.20[d]	1.88[d]
November	8.06	2.86	2.16
December	8.90	2.37	1.96

[a]INDECA, 1973.

[b]Price in Q per 1,000.

[c]Price in Q per net of 25 dozen.

[d]Harvest month(s) used in this analysis.

will depend on local rainfall patterns, the closeness of the land to a water source, and the amount of time the farmer devotes to hand carrying water.

Average monthly wholesale prices were used to determine prices for the five vegetable activities considered here. Prices for each activity were selected by looking at monthly rainfall and temperature data to determine the earliest and latest possible planting dates as well as the amount of time required for the vegetable to reach maturity. Within the limits imposed by climatic and agronomic data the farmer was assumed to select the most favorable average harvest price. This determined the month of harvest which then determined the time of planting.

Alternate employment opportunities

Vegetable production was included in this study because it is frequently mentioned as an alternative to traditional crop production in the highlands. It seems reasonable to expect that one of the next research priorities for Guatemala's economic development is the identification of possible alternate employment opportunities for small farmers, particularly small highland farmers.

The present Government program of agricultural credit provision and technical assistance should be successful in increasing average yields of beans, wheat, corn, and potatoes by at least 25-50% over the next five years. Manger-Cats writing in 1970 noted that experiences of individuals and organized groups have demonstrated that yield increases of up to 50% are not difficult to attain, but that scarcity of funds, technicians and inputs has impeded the diffusion of these yield increases to the rest of the rural masses (Manger-Cats, 1970). It is anticipated that the present rural development program will be successful in reaching the rural masses, and that average yields will be increased. As yields increase, prices probably will decline unless demand for traditional crops can be increased through opening of export markets or increased domestic consumption. The expected increases in demand, however, are far less than the assumed increases in production. Hence, it is probable that prices will decline. This means that the income increases actually accruing to farmers who participate in DIGESA's agricultural credit and technical assistance program will be dependent on the interaction which takes place between higher yields, lower prices and higher input costs. Without reliable data on domestic and export demand for traditional crops it is difficult to estimate how serious the decline in prices will be and what effect it will have on farm incomes. Ironically, the effect of declining prices will probably be more serious for smaller farmers, the group this program is designed to help. These farmers already are at a precariously low income level because their production and employment alternatives both on the farm and within the village are severely limited. Small farmers will probably continue to combine farm and off-farm employment for a few more years, but eventually they will be forced to look for employment opportunities elsewhere, and in the long run, farmers with less than one hectare of land will probably move out of farming. Farming on one hectare or less of unirrigated land is simply not a viable economic alternative.

The problem facing the development planner then, is what can be done to provide these small farmers with an economic alternative at home which is sufficiently attractive to dissuade them from migrating. Some of them might find employment in vegetable production. Some of them might be absorbed by the handicraft industry. Some could go into service industries and cottage industries at the village or departmental level. There probably exist possibilities for expansion of agricultural processing industries and some expansion of agricultural service industries as well. All of these areas hold some promise for expansion of employment opportunities. There undoubtedly are other areas which would be equally promising. How can planners decide which of the various alternatives to investigate first?

One of the lessons of development has been that the answer to the question, "What can they do?" is often contained in the answer to the question, "What are they doing now?" If one looks about the highlands, one sees various types of small industries ranging from production of illegal alcohol and textiles in Salcajá, Quezaltenango to mining in Huehuetenango, broiler production in Chimaltenango, and strawberry, asparagus and mushroom production and canning in Quezaltenango. Obviously, some of the first questions for a development planner to consider are, "Which of these production activities can be expanded? What are the constraints that have limited expansion thus far? Is there anything the government can do to relieve these constraints?"

The program of agricultural and economic development which has begun with the agricultural credit and technical assistance program administered by DIGESA and BANDESA must be followed by programs and policies designed to facilitate the development of rural employment opportunities. One approach which could be followed to accomplish this task would be to assist those rural industries which already exist. People will continue to move out of traditional crop production and into other occupations. A small farmer producing traditional crops on one or two hectares of land will not be able to achieve an acceptable income level from crop production. His contribution to the national economy will always be negligible and he is likely to become increasingly dissatisfied with his situation. He will always be a candidate for migration to the south coast or to Guatemala City. In order to develop rural areas and slow out migration it is necessary: (1) to identify industries that are producing and which have the potential to expand; (2) to determine the major constraints impeding development of these industries; and (3) to create those institutions and policies which will remove existing constraints and facilitate the growth of small industry. This may require creation of an agency to conduct feasibility studies for small industry, or creation of a marketing office to gather price and transportation information for industry. The exact steps needed to facilitate industrial development and rural employment can only be determined by people who know Guatemala very well. They cannot be specified here. One can, however, suggest that now is the time for Guatemala to assess the effects of the present development program and begin planning for the next program. The agricultural credit and extension program which is in effect today represents only a first step toward the development of the rural areas. The next step must be aimed at solving the problem of employment creation for those workers who eventually will leave agriculture.

Vegetable production activities

The vegetable production activities investigated here represent employment and income earning alternatives to traditional crop production rather than an attempt to estimate the income potential which exists from vegetables. As was mentioned earlier, most vegetables have more stringent water requirements than do the traditional crops. Vegetables, as a group, are also more perishable than are field crops and will require more care in marketing. Timeliness of planting, disease and insect control, and harvest will also be more important for vegetable growers than for traditional farmers. In short, vegetables require more management skills, more capital, and more water than do traditional crops. The attempt made here to include vegetables as an alternative for the small traditional crop farmer recognizes these differences. In this analysis only land close to water can be used for vegetable production and then only if the farmer has the management knowledge required to grow vegetables. Capital for vegetable production is assumed to be available through the Government's credit program for diversified crop production.

The vegetables chosen for consideration in this analysis are carrots, beets, and onions. The main reasons for considering these rather than some other crops were, first, that these crops are currently being grown in the highlands. Second, they are not as perishable as some of the other vegetables. Third, being root crops they are hardier and need less water than do the leafy vegetables; hence, they are more suitable to rainy season production on non-irrigated land. Fourth, the harvest period for these crops can often be stretched out by either leaving some of the less mature vegetables in the ground or by harvesting and then storing them in a cool place. This is important for a small farmer who is learning vegetable production by growing them on a small scale, because it lessens the risk associated with short run price fluctuations.

The production information concerning amounts of capital, labor, water, and types of chemicals needed for growing vegetables that are used in this analysis is taken from the publication, Analisis De Actividades Necesarias Para La Producción De 11 Especias Horticolas (Hortalizas) (Johnston, ca. 1973b). This publication is based on information obtained from vegetable production experts who were asked about vegetable production in their geographical and technical area of expertise. In some cases, the expert opinions differ due to the use of different technologies by different vegetable growers in different areas. Data provided by sources 1, 4, and 5 were given more weight in estimating production coefficients, because these sources had worked primarily as small farmers or with small farmers in different parts of the altiplano.

Vegetable activities included in the model

Table 4.17b summarizes most of the production data needed for the linear programming model. Only one technology is considered for each vegetable. This is the technology judged representative of small farm vegetable production on the altiplano by the experts interviewed. There are two activities for production of beets and carrots because the growing time required for these crops was short enough (or the rainy season long enough) that it was possible to specify two possible planting and harvesting dates. The growing season for onions is longer, and consequently, it was felt that only one onion planting and harvest period would be appropriate for the highland producer who did not have irrigated land.

Capital and labor requirements are given in Table 4.17b. The amounts of chemicals needed and hours required for application as presented in the original interviews with vegetable experts pertained to recommendations for preventive treatments and as such were always prefaced with a phrase such as, "If there is not a serious problem, this would be an adequate dosage or treatment." Recognizing that serious insect and disease problems do occur from

Table 4.17a. Explanations of row headings in Table 4.17b

Row no.	Row heading	Explanations of row headings[a]
1	KT (Q)	The total amount of capital required to produce this vegetable on 1 cuerda (0.04 ha) of land.
2	LT (hrs)	The total labor requirements for this vegetable on 1 cuerda of land.
3	YV	The yield of this vegetable per cuerda.
4	PD	An estimate of the month and the days when planting would probably occur.
5	TD	The month and the days when transplanting would take place.
6	HP	The probable duration of the harvest period.
7	PV (Q)	The price the vegetable is expected to sell for.
8	DS	The number of days the vegetable is in a seedbed.
9	DAT	The number of days after transplanting before harvest begins.

[a]The cuerda referred to below is always the standard cuerda containing 625 square varas.

Table 4.17b. Vegetable production information[a]

Row nos.	Row headings	Early beets	Later beets	Green onions	Early carrots	Later carrots
1	KT (Ω)	23.29	23.29	26.00	16.43	16.43
2	LT (hrs)	229	230	292	302	290
3	YV	399 doz.	399 doz.	16,000 med. size	500 doz.	500 doz.
4	PD	24-31 May	23-30 June	1-7 May	1-7 May	1-7 June
5	TD	1-7 July	1-7 August	15-21 June	None	None
6	HP	1-30 Sept.	1-30 Oct.	10-30 Oct.	1-25 Sept.	1-25 Oct.
7	PV (Ω)	0.065 per doz.	0.07 per doz.	7.00 per 1000	0.088 per doz.	0.088 per doz.
8	DS	35	35	45	None	None
9	DAT	60	60	135	120	120

[a]Johnston, ca. 1973b.

time to time in vegetable production, the recommended amounts of capital and labor have been increased by 10% in this study. This provides a more realistic estimate of the amounts of capital and labor required by small vegetable producers.

Row 2 of Table 4.17b contains information on the total labor hours required to grow each of the vegetables. The slight difference in labor hours required to grow early vs. later beets and early vs. later carrots is a consequence of differences in monthly rainfall averages and planting dates for the two activities. The rest of Tables 4.17a and 4.17b should be self-explanatory.

CHAPTER V. ORGANIZATION AND PRESENTATION OF THE RESULTS

The Experimental Design

The small farmer faces a number of constraints which affect his ability to produce crops, sell labor, and earn an acceptable income for himself and his family. In this study, a model has been built which attempts to approximate the interaction taking place between productive activities and constraints on the small highland farm. The model will be used to demonstrate how relaxation of these constraints can affect the farmer's income, the optimal composition of crops he produces, and the extent to which he is fully employed.

The major types of resources which the farmer has to work with are: land, labor, capital, and knowledge. In Table 5.1, these general categories have been subdivided into specific resource components and the various levels which each resource component takes in the analysis are listed.

The choice of the relevant parametric variations

Table 5.1 presents eight specific resources whose levels are varied. Six of these resources are assigned only two levels; one resource (potato land) has three possible levels; and one resource (knowledge) has four possible levels. These levels could be combined in 384 different ways ($2^5 \times 3 \times 4 = 384$), some of which are more important than others. One way to judge the relative importance of the different resource sets or combinations would be to solve the model 384 times. This would be a lengthy, costly, and confusing

Table 5.1. Resources selected for consideration

General category	Resource	Levels considered
Land	Hill and valley land	1. 0.5 ha hill land and 0.5 ha valley land
		2. 1.5 ha hill land and 1.5 ha valley land
Land	Vegetable land[a]	1. None
		2. 0.0437 ha
Land	Potato land	1. None
		2. 1.0 ha
		3. 3.0 ha
Labor	Hired labor	1. None
		2. Ten men
Working capital	Savings	1. Q50
		2. Q150
Working capital	Credit	1. None
		2. Crop specific credit
Knowledge	Technology levels for traditional crops	1. Traditional or low, level TL0
		2. Present day intermediate, level TL1
		3. Present day high, level TL2
		4. Very high (only for potatoes), level TL3
Knowledge	Vegetable[a] production knowledge	1. Low level, level 0--only knowledge of beet production.
		2. High level, level 1--knowledge of beet, onion and carrot production

[a]Vegetable land and vegetable knowledge both limit vegetable production. Only one of these will be binding in any given solution. They are actually a composite resource since knowledge without land and land without knowledge would be of no value.

process. Some of the 384 optimal solutions would be identical, because increasing the level of a resource will affect the optimal solution only if the resource was previously in short supply. Many of the 384 solutions would be similar even though they were not identical and would contribute very little to our understanding of small farm production. Obviously, a method must be devised to select only the more important changes in the farmer's set of resources.

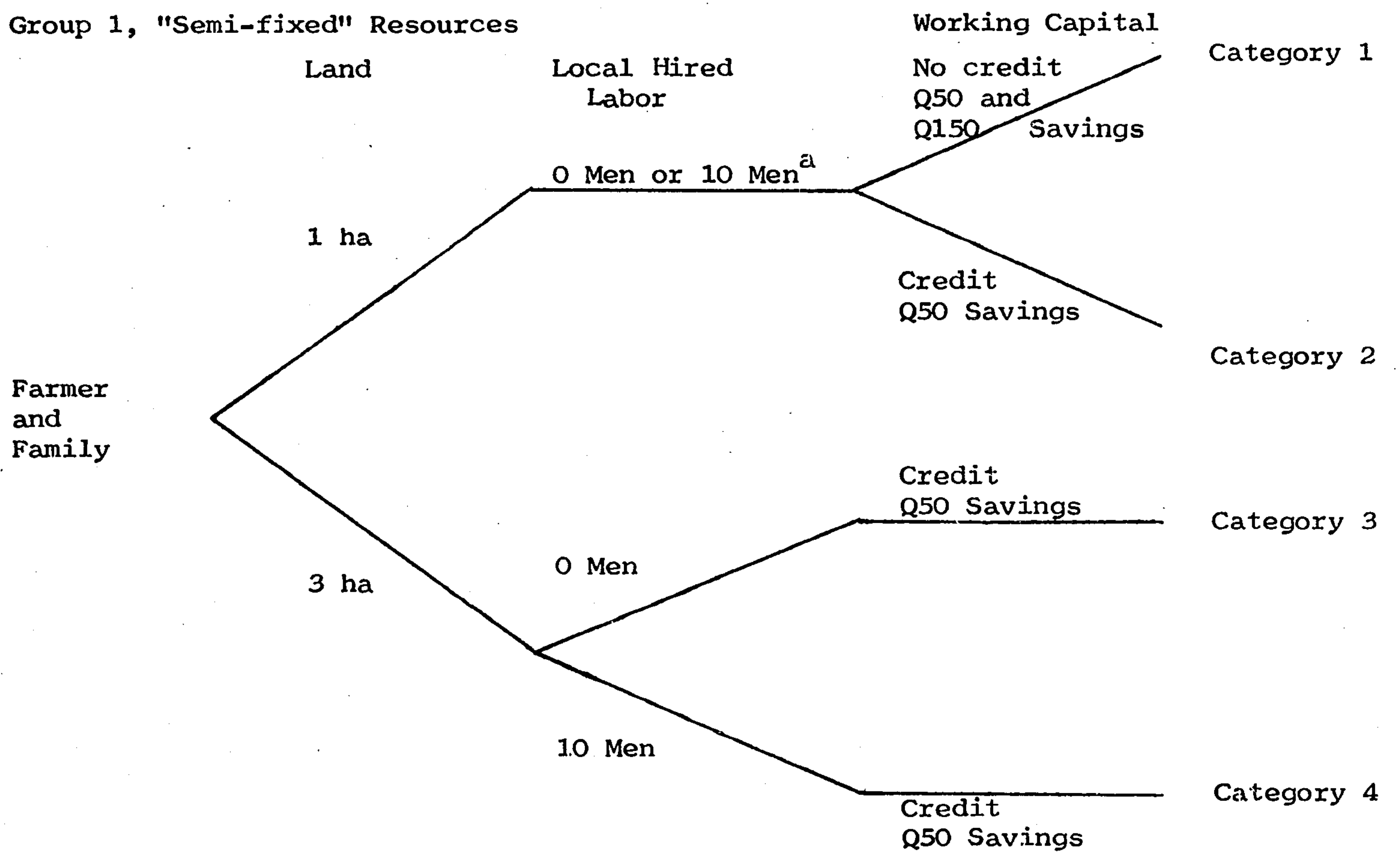
The method used to reduce the number of resource sets was to establish a ranking among the resources and to follow a smaller to larger progression of resource sets. In other words, the study begins with a relatively small resource set that describes the position many farmers find themselves in today. Successive resource sets then become gradually larger and richer. In this way, the potential for increasing farm family incomes through agricultural development programs is depicted in a step by step fashion as the restrictions imposed by one limiting resource after another are slackened or released.

<u>Ranking of resources into categories and then into resource sets</u>

The ranking used here reflects the importance of each resource to the farmer, the potential availability of each resource, and the degree to which each resource influences the composition and magnitude of the variables in the optimal solutions. Resources are classified into three groups: (1) hectares of crop land, availability of local hired labor, availability of credit and level of savings (working capital); (2) hectares of potato land and level of vegetable knowledge; (3) level of crop knowledge. These groups provide a method of organization which will allow resource sets to be presented in the smaller to larger progression mentioned earlier.

The first group is the traditional set of resources studied in economics: land, labor, and capital. These are fundamental resources whose levels are important for any economic study. The levels which these three resources may take were presented in Table 5.1 Figure 5.1 illustrates how the different levels these resources may take are combined to form categories of resource sets. Resources in Group 1 are defined as "semi-fixed" resources, because their levels vary between categories, but are fixed within each category (the level of personal savings is an exception because it takes on two values in Category 1. It is, however, fixed in the other three categories and is consequently regarded as being a "semi-fixed" resource). Figure 5.1 shows us that the importance of different levels of crop land may be investigated by comparing results from Categories 2 and 4. The importance of hired labor may be investigated by comparing results of Categories 3 and 4. The importance of credit may be investigated by comparing results of Categories 1 and 2.

The second group of resources consists of potato land and the level of vegetable knowledge. These are important resources (particularly potato land), but were not considered to be as fundamental as land, hired labor, and working capital, because the number



[a]The results in Categories 1 and 2 are identical for solutions in which either zero or ten hired laborers are available because no hired labor is needed when the family has only 1 ha of crop land.

Figure 5.1. Levels of the "semi-fixed" resources in the four categories

of farmers who have potato land or a high level of vegetable knowledge is quite small compared to the total number of traditional farmers. Furthermore, this number must remain small if potatoes and vegetables are to continue to be highly profitable crops. Still, it is interesting to know the effects which different levels of farm size, local labor availability, and availability of working capital can have on potato and vegetable farmers' income and employment levels. Consequently, these resources are allowed to take on different levels within each category. These resources are defined as "semi-variable" resources, because they are allowed to take on different levels within each category. Each different combination of resources consisting of a set of semi-fixed resources (from a given category) and a set of semi-variable resources (potato land and the level of vegetable knowledge) is defined as a "resource set." For example, a resource set could consist of the resources: 1 ha of crop land; 10 hired laborers available; no credit and Q50 savings (Category 1); plus zero hectares of potato land; and a low level of vegetable knowledge. This is a set in which all resources are at their lowest level, and, consequently, it will be the set used to begin the analysis, Resource Set 1A. The A signifies that personal savings are at the level Q50. Resource Set 1B consists of the same set except that personal savings are at the level Q150.

The third group of resources consists of different levels of crop knowledge. The level of crop knowledge is varied within each resource set to estimate how a program of technical assistance, which increases the farmer's level of crop knowledge, could affect the income and employment opportunities of a small farmer with this set of resources. For example, the first three solutions examined are solutions for Resource Set 1A in which the farmer is given crop knowledge level TL0 in the first solution, level TL1 in the second solution, and level TL2 in the third solution. The levels of crop knowledge associated with each resource set are identified when the resource sets are presented. Levels of crop knowledge are defined as "variable" resources in this study, because their levels vary within each category and within each resource set. Table 5.2 presents the resources which are defined as semi-fixed, semi-variable, and variable in each of the four categories, as well as the resource sets which belong to each category.

Category 1 in Table 5.2 represents the situation experienced by a poor highland farmer in 1973. This farmer is assumed to have one hectare of land, and he does not have access to credit. Two levels of savings are investigated as sources of working capital. Ten men are available as a supply of local hired labor in any given quarter. Their availability will, however, be irrelevant because the farmer and his family are able to supply all labor requirements for crop production activities when farm size is limited to one hectare. Semi-variable resources in Category 1 include two levels of vegetable knowledge and two levels of potato land.

Category 2 continues the analysis for a farmer with one hectare in 1973. The farmer's resource set is expanded here by assuming that

Table 5.2. Presentation of the four categories used in the analysis

Category	Semi-fixed resources[a]	Semi-variable resources[b]	Variable resources[c]	Resource sets
1	(1) 1 ha of crop land (2) No credit (3) Q50 and Q150 savings (4) 10 hired laborers	(1) Vegetable knowledge (2) Potato land	(1) Crop knowledge level	1A, 1B, 2A, 2B, 3A, 3B
2	(1) 1 ha of crop land (2) Gov't credit (3) Q50 savings (4) 10 hired laborers	(1) Vegetable knowledge (2) Potato land	(1) Crop knowledge level	4, 5, 6
3	(1) 3 ha of crop land (2) Gov't credit (3) Q50 savings (4) 0 hired laborers	(1) Vegetable knowledge (2) Potato land	(1) Crop knowledge level	7, 8, 9, 10
4	(1) 3 ha of crop land (2) Gov't credit (3) Q50 savings (4) 10 hired laborers	(1) Vegetable knowledge (2) Potato land	(1) Crop knowledge level	11, 12, 13 14, 15

[a]The levels of these resources are fixed within each category. The levels vary between categories.

[b]The levels of these resources are variable within each category and between resource sets of a given category. The levels are fixed within individual resource sets.

[c]The level of crop knowledge is variable within each category and within all resource sets.

he participates in the Government's small farm credit program. Only one level of savings is considered, Q50, since the farmer now has credit. Again, ten hired laborers are available to the farmer although he does not use them. The semi-variable resources are vegetable knowledge and land suitable for potato production.

Category 3 expands the resource set in Category 2 by assuming that the farmer now has 3 ha of land instead of just one hectare. He continues to participate in the Government credit program and to have Q50 savings. As the farmer's land rises to three hectares, availability of local hired labor is limited to zero men in anticipation of a possible shortage of labor on this larger farm. The semi-variable resources continue to be vegetable knowledge and potato land.

Category 4 completes the analysis. As in Category 3, the farmer is assumed to have 3 ha of land, access to Government credit and Q50 savings. His resource set is increased here by giving him access to ten hired laborers. The semi-variable resources are again vegetable knowledge and potato land.

Presentation of Resource Sets in Category 1

One of the most important insights to be gained from analysis of the optimal solutions in Category 1 is an understanding of the role of working capital in small farm production. Since the farmer does not have access to Government or private credit, he is forced to rely upon personal savings for all his working capital. Two levels of savings, Q50 and Q150, are used to demonstrate the importance of working capital.

Given two levels of savings, two levels of knowledge for vegetable production, and two levels of potato land, it is possible to specify eight resource sets in Category 1. Six of these resource sets were considered important enough to warrant finding solutions for them. The levels of personal savings and the semi-variable resources (vegetable knowledge and potato land) for each of these resource sets are presented in Table 5.3.

Each of the six resource sets presented in Table 5.3 defines a set of resources against which the farmer's level of crop knowledge is varied. Solutions for three levels of crop knowledge are found for each resource set. Table 5.4 specifies an identification number and identifies the level of savings, potato land, vegetable knowledge and crop knowledge for each solution. Solutions for Resource Sets 1A and 1B are found by combining the resource levels in each resource set with the three lowest levels of crop knowledge (TL0, TL1, TL2). The highest level of crop knowledge (TL3) is not combined with these sets because knowledge level TL3 is required for only the most advanced method of potato production. Since Resource Sets 1A and 1B have no potato land, they cannot use crop knowledge level TL3. Resource Sets 2A, 2B, 3A, and 3B are also combined with only three of the four levels of crop knowledge. For these sets, only the three highest levels of knowledge are used, because we wish to see how inclusion of the resource potato land can alter the

Table 5.3. Resource sets in Category 1

Resource set	Savings level (Q)	Level of semi-variable resources
1A	50	Low level of vegetable knowledge, no potato land
1B	150	Low level of vegetable knowledge, no potato land
2A	50	Low level of vegetable knowledge, one ha of potato land
2B	150	Low level of vegetable knowledge, one ha of potato land
3A	50	High level of vegetable knowledge, one ha of potato land
3B	150	High level of vegetable knowledge, one ha of potato land

optimal solutions of Sets 1A and 1B. Crop knowledge level TL0 becomes unimportant here because the three highest yielding potato activities require a crop knowledge resource of at least level TL1. If the farmer has potato land but does not have a crop knowledge level of TL1, he cannot grow potatoes. The solutions for a farmer with crop level TL0 and potato land would be very similar (or identical) to solutions for Resource Sets 1A and 1B in which the farmer does not have potato land.

Table 5.4. Solution identification numbers for the resource sets in Category 1

Solution number	Resource set	Savings level (Q)	Ha. of potato land	Level of vegetable knowledge	Crop knowledge level
1	1A	50	0	low	TL0
2	1A	50	0	low	TL1
3	1A	50	0	low	TL2
4	1B	150	0	low	TL0
5	1B	150	0	low	TL1
6	1B	150	0	low	TL2
7	2A	50	1	low	TL1
8	2A	50	1	low	TL2
9	2A	50	1	low	TL3
10	2B	150	1	low	TL1
11	2B	150	1	low	TL2
12	2B	150	1	low	TL3
13	3A	50	1	high	TL1
14	3A	50	1	high	TL2
15	3A	50	1	high	TL3
16	3B	150	1	high	TL1
17	3B	150	1	high	TL2
18	3B	150	1	high	TL3

The method of presentation used here is to examine the optimal solutions for Resource Set 1A in some detail to familiarize the reader with the model and the types of results which are being generated. The other resource sets of Category 1 will then be presented briefly. Emphasis in the text is on presenting an overview of the important similarities and differences between the eighteen optimal solutions presented in Table 5.4. More detailed information for each solution is found in Appendix A.

Resource Set 1A--Solutions 1, 2, 3

This is the poorest of the resource sets considered in Category 1. The farmer has only Q50 savings, a low level of vegetable knowledge and no land suitable for high yield potato production. Figure 5.2 and Table 5.5 summarize the more important results found in the three optimal solutions for Resource Set 1A. Table 5.5 shows the reader the types of information contained in Appendix A.

The crop knowledge level of TLO in the first solution of Table 5.5 represents the level of technology used by many poorer highland farmers. The income earned is quite low, and the picture of peasant life suggested by these results is not a very bright one. The family earns a total income of Q443.47. Only 24% of this total income comes from sale of crops. The remainder comes from sale of migratory and local labor. The farmer migrates for the full sixty days allowed in both third and fourth quarters and earns Q93.20 from selling migratory labor. He and his family together earn Q244.01 from selling labor locally. This could be an overestimate because the model

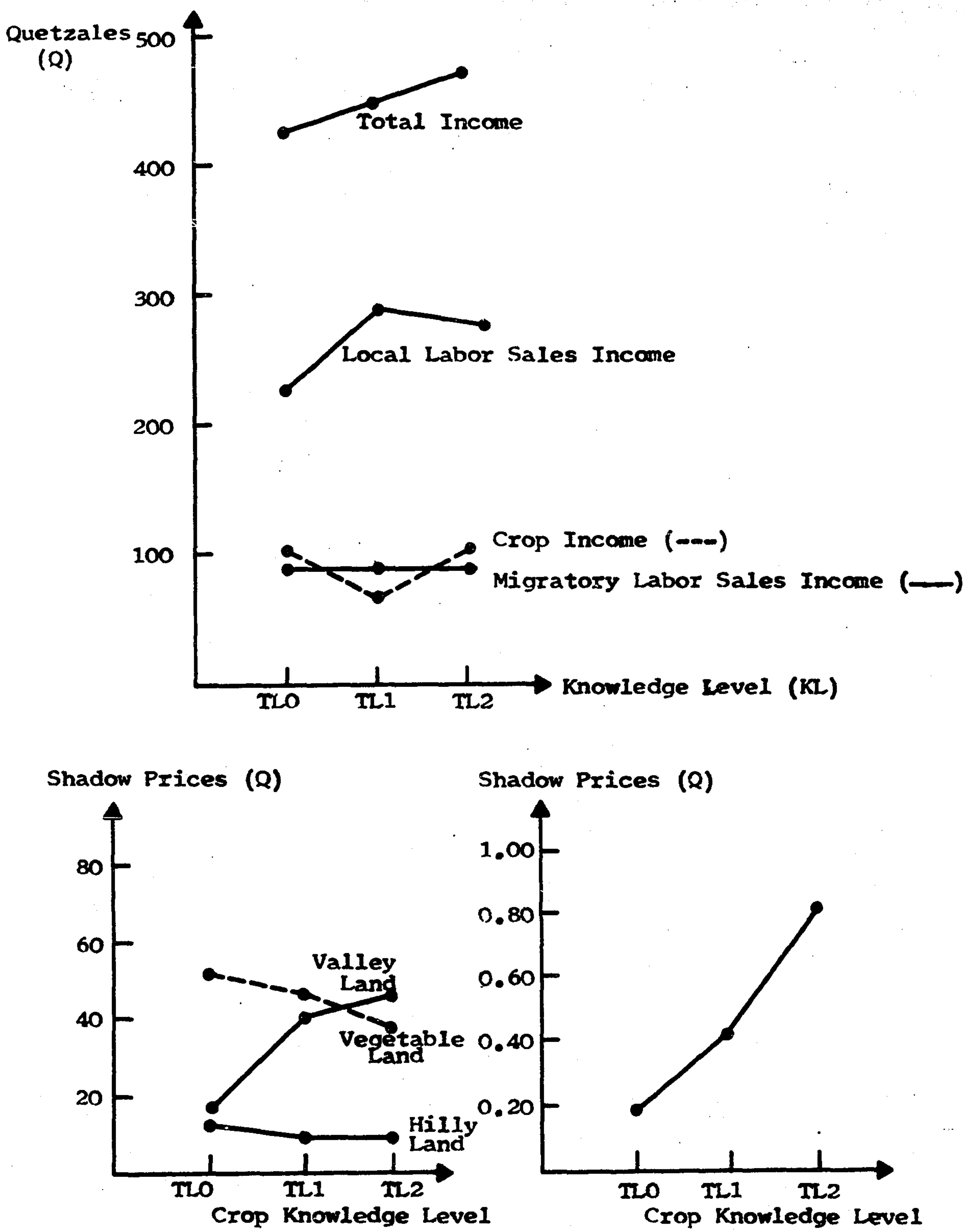


Figure 5.2. Levels of income and shadow prices in Resource Set 1A

Table 5.5. Optimal solutions under Resource Set 1A of Category 1[a]

Variable[b]	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Optimal solution number	1	2	3
Total income (Ω)	443.47	467.69	492.07
Crop income (Ω)	106.26	71.99	109.72
Migratory labor sale income (Ω)	93.20	93.20	93.20
Local labor sale income (Ω)	244.01	302.79	289.15
Total labor hours hired	0	0	0
Total hours used on crops	1173	393	570
Ha. of corn alone, V, 4	0	0	0.1314
Ha. of wheat, V, 3	0	0.3323	0
Ha. of wheat, HV, 2	0.2617	0	0
Ha. of milpa, V, 3	0	0	0.3686
Ha. of milpa, V, 2	0	0.1677	0

Ha. of milpa, V, 1	0.4215	0	0
Ha. of milpa, H, 2	0.3168	0	0
Shadow price on potato land[c]	604.44	499.38	298.96
Shadow price on vegetable knowledge[d]	57.30	49.55	38.38
Shadow price on savings[e]	0.19	0.44	0.86
Shadow price on vegetable land[c]	0	0	0
Shadow price on hilly land[c]	6.02	0	0
Shadow price on valley land	11.38	41.02	47.96
Labor hours sold locally	3253	4033	3856

[a]Semi-variable resources are fixed at: (1) a low level of vegetable knowledge, and (2) zero ha of potato land. Personal savings is fixed at Q50.

[b]The letters H and V following the ha of crops produced refer to whether the activity is carried out on hilly land, valley land, or a combination of hilly and valley lands (HV). The numbers 1, 2, 3, 4 describe the relative amounts of capital used in the activity. For example, Milpa, V, 3 uses more working capital than Milpa, V, 2.

[c]Shadow price in Q per ha.

[d]Shadow price in Q--the amount by which income would be increased if the farmer had a high level of vegetable knowledge.

[e]Shadow price in Q per additional Q of savings.

assumes that there is an unlimited demand for local labor sales. The only limitation placed upon local labor sales is that the family cannot sell more labor than it possesses. The crops produced in this solution are milpa and wheat. The farmer devotes 73% of his land to milpa and the remainder to wheat. The shadow price on savings is Q0.19 indicating that if the farmer had another Quetzal of savings to devote to crop production, it would increase his income by 19¢. This means that one Quetzal invested in crop production activities would return Q1.24 by harvest time because there is an opportunity cost of 5% associated with using savings for crop production (Q1.24 - Q1.05 = Q0.19). This is a fairly low return to capital for a peasant farmer. Various studies of peasant agriculture around the world have observed significantly higher returns to working capital. Higher returns to working capital will also be observed in successive solutions of this model. Why then is the return to working capital so low in this first solution? One factor explaining this is the farmer's very limited level of crop knowledge in the first solution. When the farmer is aware of more profitable capital intensive technologies, the shadow price on capital will rise. A second factor explaining the low shadow price on savings (working capital) is that the farmer and his family are given an opportunity to sell all their labor at 7.5¢ per hour; they are never unemployed. Therefore, hours spent on cropping activities must return more than 7.5¢ per hour to compete with local labor sales activities for the family's time. If the family did not have this alternative use for its labor, the shortage of working capital would be more serious and the shadow price on capital would be higher. Shadow prices on land are also quite low (Q6.02 and Q11.38 per ha for hilly and valley land respectively. The most important factors explaining the relatively low shadow prices on land are: (1) the farmer is already short on capital, and at this point, capital is the more serious constraint; (2) the farmer has an alternate use for his labor, i.e., selling labor locally; and (3) the farmer's knowledge of new technologies is very limited. The shadow price on potato land is deceptively high in this first solution, Q604.44/ha. Potatoes are quite an attractive crop if you can grow them, but the farmer in Solution 1 cannot grow them, because he has no potato land and his level of crop knowledge is too low to allow him to adopt high yield potato technologies. The shadow price on vegetable knowledge of Q57.30 indicates that if he had one cuerda of land suitable for production of green onions, and if he knew how to grow them, he could increase his income by Q57.30.

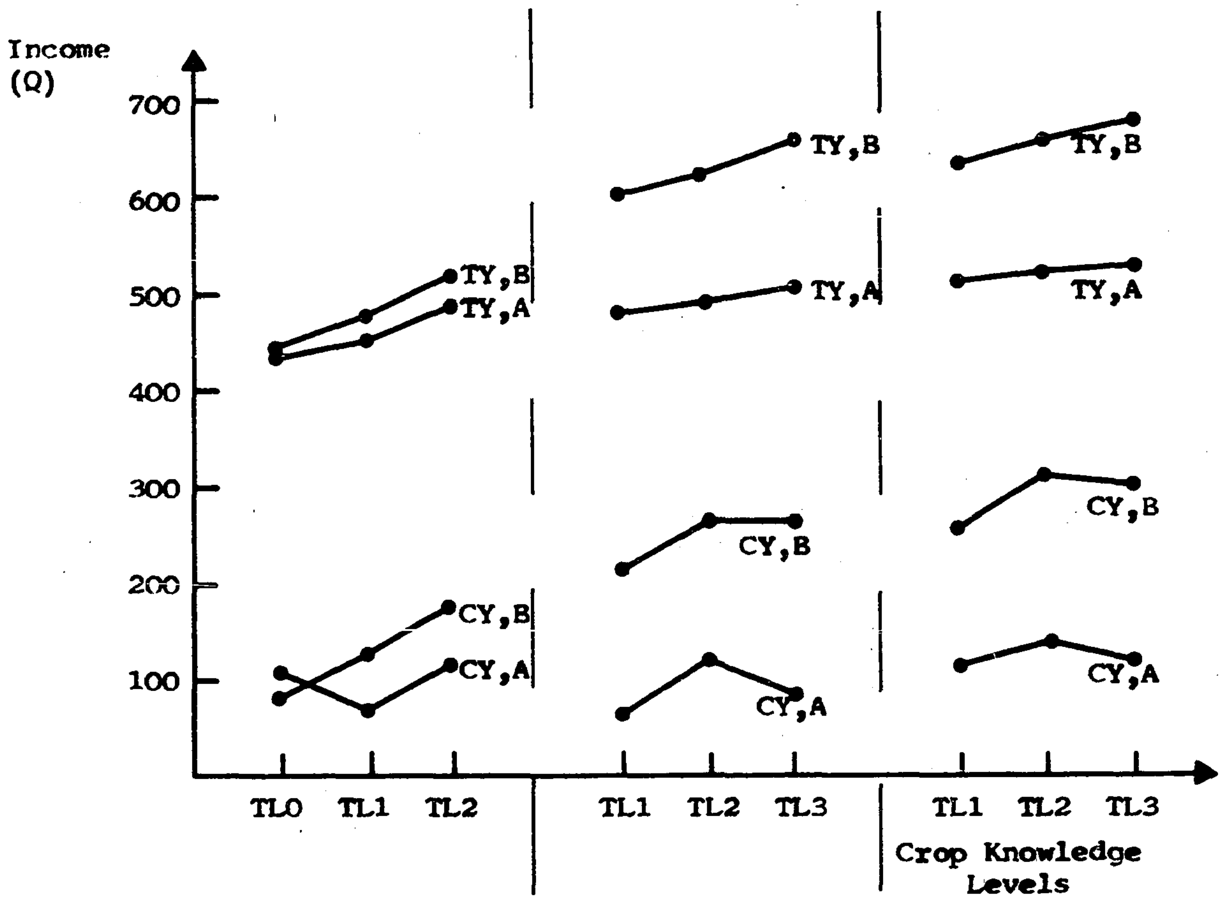
Increasing the farmer's level of knowledge to TL1 produces an interesting result. His total income increases by Q24.22 even though his crop income decreases by Q34.27. This is because he adopts the more profitable crop technologies which require a knowledge level of TL1. These technologies usually require a little less labor input than the traditional technologies on a per hectare basis which results in some labor being freed for local sale. Still more labor becomes available for local sale because the level of savings is not high enough to permit the farmer to use the entire one hectare. He uses what savings he has to adopt new technologies on his more fertile valley land and lets the hilly land lie fallow. Actually, the farmer would probably rent the hilly land if he could find a renter. This possibility has not been included in the model due to the difficulty of determining rental rates. If the farmer wanted to rent to another traditional farmer who has a resource set similar to the one just examined in the first solution, the shadow price on hilly land in Solution 1 indicates that he would have to rent his one-half hectare of hilly land for Q3.01 or less. In later solutions we will see that shadow prices on hilly lands are not always this low; rental rates are probably higher than Q6.02 per hectare.

Crop production in this solution accounts for only 15% of total income. The crops produced are again wheat and milpa. Approximately 33% of the land is used for wheat, 17% is used for milpa and 50% (the hilly land) lies fallow. The shadow price on savings in this second solution rises to Q0.44 indicating that the shortage of capital is even more restrictive now that the farmer knows of other technologies but cannot use all his land due to a shortage of working capital. Here again, this shadow price would be even higher if we had not assumed that the farmer and his family could sell as much labor as they wanted locally. If the family members could not find employment locally, they would devote less of their savings to the newer technologies and use all their land for cropping activities. They certainly would not use all their savings to produce crops by adopting newer technologies and, consequently, experience a reduction in crop income if crop income were their only or their major source of income. The shadow prices on potato land and vegetable knowledge decrease somewhat in this solution because knowledge of new crop technologies makes production of milpa and wheat more competitive with vegetable and potato production.

Increasing the farmer's crop knowledge resource to TL2 allows the farmer to increase total income by Q48.60 over the income he earned in the first solution. His crop income increases only marginally by Q3.46, but his local labor sales are increased by Q45.14. This is again due to the fact that he farms only his valley land and lets his hilly land lie fallow. As in the previous solutions, he continues to grow milpa and wheat. The composition of his crop production changes here. He now devotes 37% of his land to milpa, 13% to wheat and lets 50% (his hilly land) lie fallow. The shadow price on savings in this third solution rises to Q0.86, and the shadow price on valley land is Q47.96. These higher shadow prices reflect the fact that since he now has knowledge of new technologies, his capital and his land resources are more valuable to him.

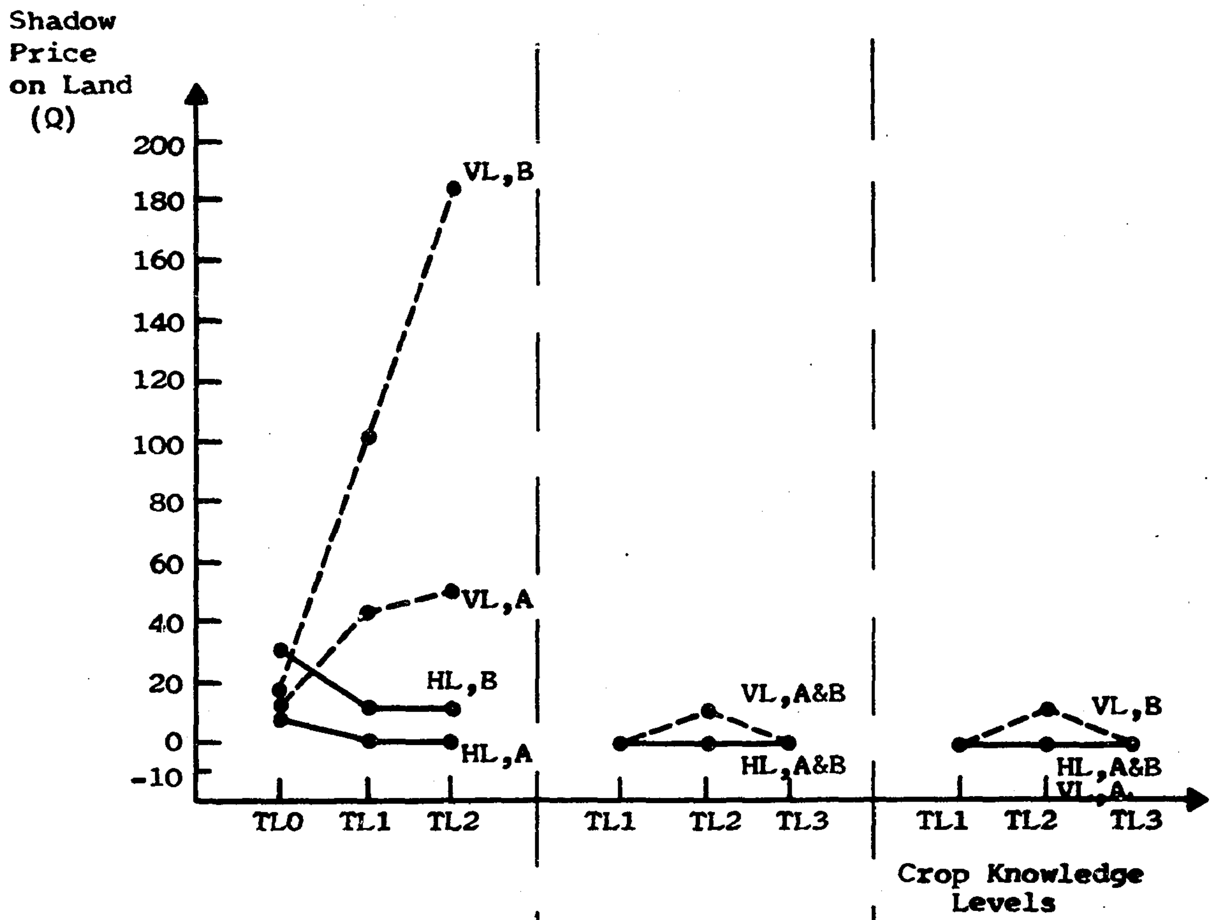
Resource Set 1B--Solutions 4, 5, 6

Resource Set 1B differs from Set 1A in that the farmer's level of personal savings in Set 1B is increased to Q150. The increased level of savings allows the farmer to increase his total income in all three solutions. Fairly substantial increases in crop income are recorded for solutions in which the farmer has a crop knowledge level of TL1 or TL2. For example, cropping income in Resource Set 1B increases by Q56.74 over cropping income in Resource Set 1A for farmers with knowledge level TL1. The crops produced in Set 1B are milpa, wheat and corn alone. With the additional Q100 savings available in Set 1B, the farmer is able to use all his land. Hilly land no longer lies fallow but rather becomes a constraint. The shadow price on hilly land increases from Q0.00 to Q16.32 in solutions where the farmer has crop knowledge levels TL1 and TL2. The shadow price on valley land is also increased. For farmers with crop knowledge level TL2, the shadow price on valley land is increased from Q47.96 to Q182.83 per hectare. Shadow prices on savings ranged from Q0.19 to Q0.86 in Set 1A; in Set 1B they fall to zero for all three solutions. The farmer doesn't need the full Q150 savings for crop production activities with this limited resource set. Some of the more important results for Resource Sets 1A and 1B have been incorporated into Figures 5.3, 5.4 and 5.5. These figures summarize all the results in Category 1 and give the reader an overview not only of the results presented here but also of the results to follow. Each of these figures is divided by dotted lines



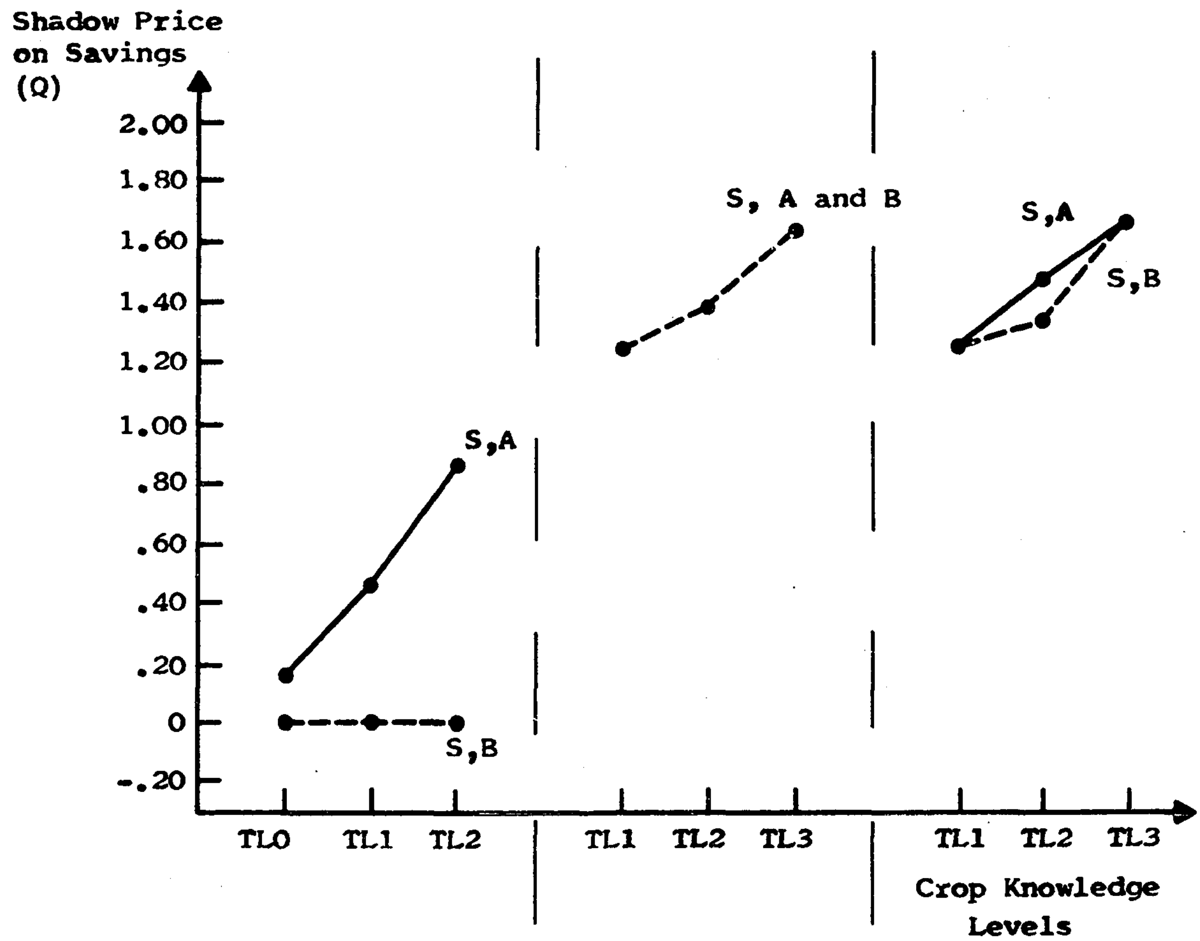
Semi-Variable Resources	Sets 1A, 1B			Sets 2A, 2B			Sets 3A, 3B		
1. Ha. of potato land	0	0	0	1	1	1	1	1	1
2. Vegetable knowledge level	low	low	low	high	high	high	high	high	high

Figure 5.3. Levels of total income (TY) and crop income (CY) estimated by solutions in Category 1



Semi-variable Resources	Sets 1A, 1B			Sets 2A, 2B			Sets 3A, 3B		
1. Ha. of potato land	0	0	0	1	1	1	1	1	1
2. Vegetable knowledge level	low	low	low	low	low	low	high	high	high

Figure 5.4. Shadow prices for hilly land (HL) and valley land (VL) estimated by solutions in Category 1



Semi-variable Resources	Sets 1A, 1B			Sets 2A, 2B			Sets 3A, 3B		
1. Ha. of potato land	0	0	0	1	1	1	1	1	1
2. Vegetable knowledge level	low	low	low	low	low	low	high	high	high

Figure 5.5. Shadow prices for personal savings (S) estimated by solutions in Category 1

into thirds. The section of each graph we are concerned with is the third on the left in which the results of solutions for sets 1A and 1B have been plotted. The levels of the semi-variable resources in each resource set are identified below the figure. For example, in Resource Sets 1A and 1B, the semi-variable resources are fixed at the levels zero ha of potato land and a low level of vegetable knowledge. For a more extensive presentation of the results in Sets 1A and 1B, the reader is referred to the tables in Appendix A.

Resource Set 2A--Solutions 7, 8, 9

Set 2A differs from Set 1A by specifying that the one hectare of land the farmer owns is in a geographical and climatic area which is appropriate for high yield potato production. The farmer once again is assumed to have only Q50.00 savings, and capital is a very serious constraint in these solutions. The shadow prices on savings in Figure 5.5 reflect this. They are much higher for Set 2A than for Set 1A. For example, the shadow price on savings for a farmer with knowledge level TL1 in Set 1A was Q0.44. In Set 2A the corresponding shadow price is Q1.22. The composition of the crop mix changes now that high yielding potato activities are possible. Potatoes are grown in all three solutions of Set 2A although not much of the total land available can be devoted to potato production because of the shortage of capital. In Solutions 7 and 9 with knowledge levels TL1 and TL3, only potatoes are grown, and most of the land is not used. The farmers use the labor time freed from corn, milpa, and wheat production to increase their local labor sales. This is, of course, not very realistic for the reasons explained earlier in our discussion of Set 1A where a shortage of capital forced farmers to use only their valley land. For Solution 8 in which the farmer has a knowledge level of TL2, both potatoes and milpa are grown. The appearance of milpa here is due to the shortage of capital. It demonstrates that even though potatoes are a very profitable crop, milpa can sometimes compete with potatoes if the milpa is grown in a fairly technified manner. This occurs because the return to labor from milpa is considerably higher than the return to labor from local labor sales. It is more profitable for the farmer to devote some of the land to milpa rather than to rely exclusively on a very small amount of potato production and a large amount of local labor sales. This situation differs from the situation in Solutions 7 and 9 because with a knowledge level of TL2, the farmer knows about the most profitable and advanced milpa and corn activities, which were unknown in Solution 7, but does not yet have the expertise and knowledge required by the most technical means of potato production which is used in Solution 9. The shadow prices on hilly and valley land are depressed in these solutions due to the tremendous shortage of capital which exists and the fact that the farmer faces an infinitely elastic demand for his local labor sales activities. As Figure 5.3 shows, total income is increased slightly in these solutions, and cropping income remains at the same general level as in Set 1A. The solutions for Set 2A indicate that, by itself, land suitable for potato production will have only a small effect on income. The potential for increasing income through adoption of high yield potato activities is there, but it is an unrealizable potential when the scarcity of capital is so acute.

Resource Set 2B--Solutions 10, 11, 12

In this set of resources, the farmer's level of personal savings is increased to Q150. As was the case with Set 1B, this results in higher levels of total income in all three solutions. The increase in total income here, however, is much more dramatic than in Set 1B. Total income levels in Set 2B increase from the Q480-515 range to the Q610-670 range, and the average increase is about Q140. This increase is due to a rather large jump in cropping incomes in all three solutions. Income from the sale of migratory labor remains constant at Q93.20, and income from sale of local labor has an average[1] decrease of about Q15.00. Although the extra Q100 allows the farmer to achieve a substantial increase in total income by growing potatoes, much more capital could be used to achieve even higher incomes. The shadow price on savings in Set 2B remains

[1]Mention will be made of average changes in levels of different variables throughout this chapter. The average referred to is an average for the variable in the three solutions found for each resource set. In this case, the average decrease in local labor sales is Q15 for the three solutions of Resource Set 2B in which the farmer was given crop knowledge levels of TL1, TL2 and TL3.

between Q1.22 and Q1.62 as it was for Set 2A. The farmer is still not able to use all his land, and the shadow prices on land remain as they were in Set 2A. The composition of crops grown as a result of the additional Q100 of personal savings is roughly unchanged. Solutions 10 and 12 grow only potatoes. Solution 11 (TL2) grows potatoes and milpa.

Resource Set 3A--Solutions 13, 14, 15

In Set 3A, the farmer is assumed to possess a higher level of vegetable knowledge than he had in Set 2A. This allows him to include one cuerda of carrots and/or green onions among his crop production alternatives. All other resources remain at the same levels as in Set 2A. In spite of the fact that the farmer only has Q50.00 savings and that the shadow price on savings remains very high (between Q1.22 and Q1.62 as it was in Set 2A), the farmer allocated part of his savings to production of green onions. In all three solutions, the farmer grows one cuerda (the maximum allowed) of green onions. Total income and crop income are increased by approximately Q25 and Q35, respectively, as a result of including one cuerda of onions among the production activities. One other change in the composition of crops produced is that in Solution 14 (TL2), green onions displace potatoes as the capital intensive crop being grown. The farmer in Solution 14 grows only onions and milpa. In the other two solutions, only onions and potatoes are grown. Shadow prices on land remain depressed here, because capital is still so scarce that the farmer cannot use all his land. He cannot even use all his valley land, and its shadow price falls to zero. Figure 5.4 capsulizes the shadow price movements for valley and hilly land very well.

Resource Set 3B--Solutions 16, 17, 18

Set 3B increases the supply of personal savings given in Set 3A by Q100. The results are very similar to the results found for Sets 2A and 2B. The levels of total income and crop income are a little higher in Set 3B than they were in Set 2B, but the general effect of the increased Q100 savings upon shadow prices for land and for savings is very similar to the effect seen in Set 2B (where the level of personal savings was similarly increased by Q100 over the level specified in Set 2A). In all three solutions of Set 3B, both onions and potatoes are grown. About the only difference between the solutions in Sets 2B and 3B is that in Set 3B each solution substitutes one cuerda of onions where there was a cuerda of potatoes in Set 2B.

Conclusions to be drawn from Category 1

Resources held constant in Category 1 are: one hectare of crop land; no availability of Government or private credit; and a maximum of ten hired men available to help with cropping activities each quarter. The resources allowed to vary between resource sets were the level of private savings, the amount of vegetable production knowledge, and a dummy variable which specified that the farmer's land was (or was not) geographically, climatically and agronomically suited for high yield potato production activities. The level of crop knowledge was varied both within and between resource sets of Category 1.

Category 1 has been used to reproduce the position which many small farmers in western Guatemala find themselves in. It has investigated the effects of variations in the level of savings and in the levels of crop and vegetable knowledge as well as the effect of having land suitable for potato production. Several interesting conclusions may be drawn from these eighteen optimal solutions.

The first conclusion, which is not very surprising, is that the distinction between farmers who can grow potatoes and those who cannot is important. If a farmer can engage in high yield potato activities as described in Chapter IV, he is in an entirely different league from the farmer who cannot. As more farmers acquire credit and knowledge of new potato technologies, more potatoes will be grown and the comparatively high price on potatoes probably will be decreased so that potato production will become less profitable and more comparable to corn, milpa and wheat production. Until that happens, potato farmers will be able to earn substantially higher incomes than non-potato farmers. At present, potato farmers are quite a small group. If their numbers are expanded very rapidly, much of the advantage which potatoes currently enjoy would be wiped out; hence, one cannot expect potato production to be the path which will lead large numbers of small farmers to significantly higher income levels. With this in mind, let us review the Category

1 conclusions obtained from Sets 1A and 1B in which the farmer was not able to produce potatoes.

One of the most striking aspects of the solutions presented in Sets 1A and 1B is that throughout these solutions, the amount of income earned from cropping activities is quite low. Only about 25-35% of total income is earned by sale of crops. The remainder comes from migratory labor sales and local labor sales. The exact percentage of total income earned by sale of crops varies with the farmer's level of knowledge and his savings. The greater the level of knowledge and the amount of savings, the higher the percentage of total income earned from sale of crops. The relatively high proportion of income from labor sales for the non-potato farmers is due to the fact that the family of man, wife and two teenage children has a labor supply of approximately 2.1 farm laborers, which is more than can be fully employed on a one hectare farm. When the family's supply of personal savings is limited to Q50, some of the poorer hilly land lies fallow due to the shortage of savings, but when the family has an adequate amount of savings (Q150), the family uses all its land. In some cases, the shadow prices on land become quite high. Labor is first devoted to crop production activities and migratory labor sales; any residual labor is sold locally. This result provides two important pieces of information about the small non-potato farmer in Category 1. The first is that the typical small farmer is essentially a marginal farmer. Even if he has sufficient savings or credit availability to take care of his capital needs, he and his family will not be fully employed on one hectare of land. As was seen in Figure 5.3, the total income earned in Sets 1A and 1B ranges from Q443.47 to Q524.73; at most only 35% of this comes from sale of crops. The family cannot afford to rely solely on crop income and must devote a substantial portion of its time to labor sales activities if total income is to be kept above Q300. Consequently, the farmer depicted here can only be considered a marginal farmer because off-farm labor sales are a more important source of income than sale of crops. If the farmer and his family are to be fully employed on their own farm, they must have more land.

The second important piece of information is that crop production activities in the model do compete effectively with local labor sales activities for the farmer's time. Thus, labor engaged in crop production activities is not a form of disguised unemployment. Even for the lowest level of crop knowledge (TLO) which represents a traditional type of agriculture, the farmer with adequate savings uses all his land for crop production and the shadow price on land is positive (although it is quite low). When the level of crop knowledge is increased, the shadow prices on valley land become quite large.

Figure 5.4 presents information on the shadow prices for hilly and valley land. These shadow prices sum up the situation faced by the small non-potato farmer extremely well. Figure 5.4 shows that when the farmer has Q150 savings, both hilly and valley land have positive shadow prices. This holds true regardless of the level of crop knowledge the farmer is assumed to possess. Thus, even if the farmer has an adequate amount of savings (working capital), he must have more land if he is to increase his income. When the farmer has only Q50 savings and either TL1 or TL2, his savings are in such short supply that he does not use all his hilly land but instead lets part of it lie fallow. Even though the shortage of land is absolutely critical in the sense that he must have more land to be fully employed on his own farm, his shortage of capital in the Q50 savings solutions is even more critical and prevents him from fully utilizing what land he has.

The role which extension and other educational programs can play in helping small farmers is also depicted in Figure 5.4. Since the more advanced technologies are usually employed on the better valley lands, one should look at the shadow price estimate for valley lands to see this. For instance, the shadow price on valley land when the farmer has only Q50 savings (VL,A) is increased from Q11.38 to Q47.96 as the farmer's crop knowledge is increased from TL0 to TL1. This demonstrates that knowledge of new technologies has potential to increase farm incomes even when savings are in short supply. The importance of combining knowledge of new technologies with an adequate supply of savings (working capital) is illustrated by the shadow prices on valley land when the farmer has Q150 savings (VL,B). In these solutions, the shadow price on valley land increases from Q15.29 to Q182.83 as the level of crop knowledge is increased from TL0 to TL2. A quick glance at VL,B and VL,A for Resource Sets

1A and 1B in Figure 5.4 illustrates the importance of combining an adequate amount of capital with increased crop knowledge, thereby allowing the farmer to use new cropping technologies.

The rather large differences between shadow prices on hilly vs valley lands are somewhat misleading. As mentioned in Chapter IV, survey data reported that more capital intensive, high yielding production technologies requiring higher levels of crop knowledge were used almost exclusively on the better valley lands while less capital intensive and lower yielding activities were carried out on hilly land. Consequently, in the model, the highest yielding activities require valley land, and shadow prices on valley land are higher than shadow prices on hilly land when the farmer has knowledge of these high yielding activities. If, however, more capital intensive technologies were used on hilly lands, yields on hilly land activities would increase and the shadow price on hilly land would also increase. It is likely that yields would not reach quite as high a level on hilly lands as on valley lands because valley lands are generally of a higher quality than hilly lands. Nevertheless, it seems reasonable to assume that use of more capital intensive technologies on hilly lands would increase yields significantly. This would reduce the differences in shadow prices of hilly vs valley lands shown in Figure 5.4.

Another interesting characteristic of non-potato farm production is that although the shortage of savings is fairly severe in solutions for Set 1A, shadow prices on savings fall to zero for all three solutions in Set 1B. An additional Q100 takes care of all the farmer's capital requirements on the non-potato farm.

In review, then, we may say that the non-potato farmer in Category 1 is only a marginal farmer because he does not have enough land to fully occupy the family's labor time. Since so much of his time is spent working off farm, increasing his level of crop knowledge or his supply of savings or both does not result in a substantial increase in either his crop income or his total income. If he had one more hectare of valley land, however, the shadow prices on valley land in Figure 5.4 suggest that providing him with an adequate amount of capital and knowledge of new technologies has the potential to increase his income (Solution 6) from Q524.73 to about Q700. This would be a significant improvement; the effect of giving the farmer more land will be investigated in Categories 3 and 4. Now let us turn to the solutions in Resource Sets[1] 2A, 2B, 3A and 3B in which the farmer was allowed to grow potatoes.

The situation for the farmer with potato land is quite different than the situation for the farmer without potato land. Potatoes require relatively large amounts of capital compared to corn, milpa and wheat. Consequently, the potato farmer in Category 1 is limited from increasing his income not by a shortage of land but by a shortage of savings (or working capital). This is true

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[1]The terms Resource Set and Set will be used synonymously from here on to identify a particular group or set of resources. For example, "Resource Set 1A" and "Set 1A" refer to the same collection of resources.

whether he is given Q50 savings or Q150 savings. The shadow prices on savings in these solutions range from Q1.22 to Q1.62 depending upon the farmer's level of crop knowledge. Even though potato farmers earn an average of about Q105 more than non-potato farmers, the potato farmer could potentially earn much more if he had adequate savings. The importance of additional savings upon the level of total income is illustrated by the very high shadow prices presented in Figure 5.5. It is also instructive to notice that although the overall average income for potato farmers is Q105 more than for non-potato farmers in Category 1, the average for potato farmers with Q50 savings is only about Q45 more than for non-potato farmers while the average for potato farmers with Q150 savings is about Q165 more than the average for non-potato farmers.

Although incomes are substantially higher for potato farmers in Category 1, it is interesting to note that potato farmers relied very heavily on labor sales activities to supplement their incomes. Farmers with Q50 savings earned an average of only 21% of their total income from sale of crops. Farmers with Q150 savings earned an average of 42% of total income from sale of crops. The impetus for selling large amounts of labor locally comes from the seasonal nature of potato production activities and is also due to the fact that the farmer's level of personal savings is too low to allow him to use all the labor and land he has available for potato production. Savings, not land, is the most significant constraint. In most of the solutions, the shadow prices on land are zero, and in all cases they are very low.

The Category 1 solutions show that when the farmer is given a high level of vegetable knowledge, he always grows a cuerda of green onions. Onions are even more profitable than potatoes. When onions are permitted, they sometimes displace a cuerda of potatoes. When they are not permitted, the farmer grows only potatoes in solutions with a crop knowledge level of TL1 or TL3. In solutions with a crop knowledge level of TL2, he also grows milpa on his valley lands.

Presentation of Resource Sets in Category 2

Category 2 continues the analysis for a farmer with one hectare of land by adding availability of Government credit to the farmer's set of fixed resources. Since the farmer now has access to Government credit, personal savings are held constant at Q50 throughout Category 2. The semi-variable resources in Category 2 are vegetable knowledge and potato land. As in Category 1 for solutions in which the farmer does not have potato land, only the three lowest levels of crop knowledge (TL0, TL1, TL2) are used to demonstrate the effect of increasing the farmer's knowledge through Government extension and educational programs. Similarly, when the farmer does have potato land, only the three highest levels of crop knowledge (TL1, TL2, TL3) are used to demonstrate the effect of increasing his knowledge of new technologies. Vegetable knowledge continues to be present at two levels, low and high. Potato land also is assigned only two levels, zero and one hectare. The three resource sets specified for Category 2 are presented in Table 5.6.

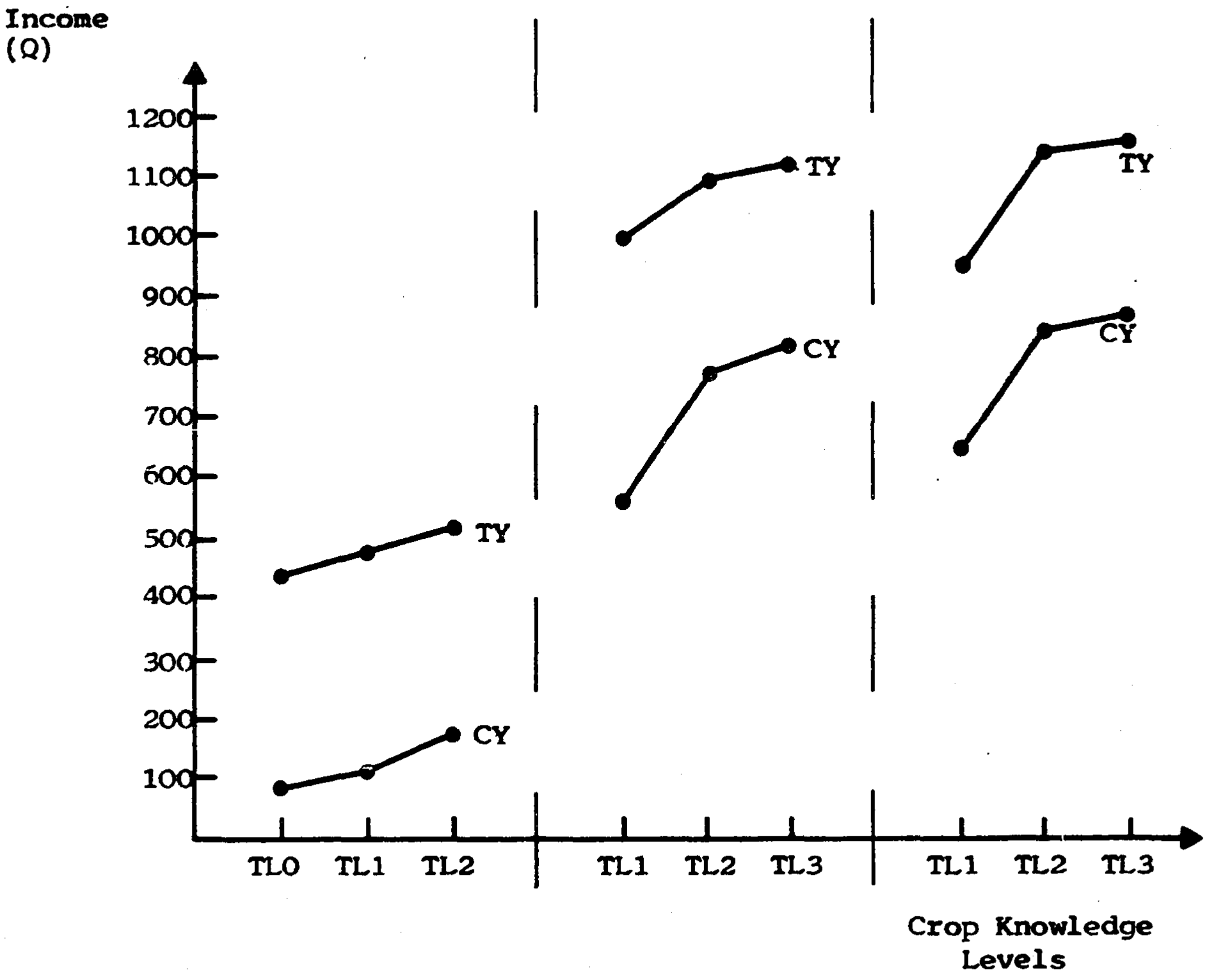
Resource Set 4--Solutions 19, 20, 21

Resource Set 4 allows further analysis of the employment and income earning potential of a small farmer with only one hectare of land and no possibility of adopting either the high yield potato activities or the more lucrative vegetable activities requiring a high level of vegetable knowledge. The farmer may be constrained from engaging in these potato and vegetable activities by lack of suitable land, insufficient knowledge, or both. Resource Set 4 assumes that the farmer has access to the Government's crop specific credit program and allows us to determine how the availability of additional working capital (which was a limiting factor in Resource Set 1A) enables the farmer to increase his crop income. With the exception of credit availability, Resource Set 4 is identical to Resource Set 1A.

Figures 5.6, 5.7 and 5.8 present information on income levels and shadow prices for solutions in Resource Sets 4, 5, and 6. In each of these figures, only the solutions in the first one-third of the figure correspond to Set 4. Figure 5.6 shows us that total income for farmers in Resource Set 4 ranges from Q446.68 to Q521.96. This range is about the same as was found for total income in Set 1B. Table 5.7 points out the similarities which exist between the levels of total income and crop income earned in Sets 1B and 4.

Table 5.6. Resource sets in Category 2

Resource set	Optimal solution number	Savings level	Hectares of potato land	Level of vegetable knowledge	Crop knowledge level
4	19	50	0	low	TL0
4	20	50	0	low	TL1
4	21	50	0	low	TL2
5	22	50	1	low	TL1
5	23	50	1	low	TL2
5	24	50	1	low	TL3
6	25	50	1	high	TL1
6	26	50	1	high	TL2
6	27	50	1	high	TL3



	Set 4	Set 5	Set 6
Semi-Variable Resources			
1. Ha. of potato land	0	1	1
2. Vegetable knowledge level	low	low	high

Figure 5.6. Levels of total income (TY) and crop income (CY) estimated by solutions in Category 2

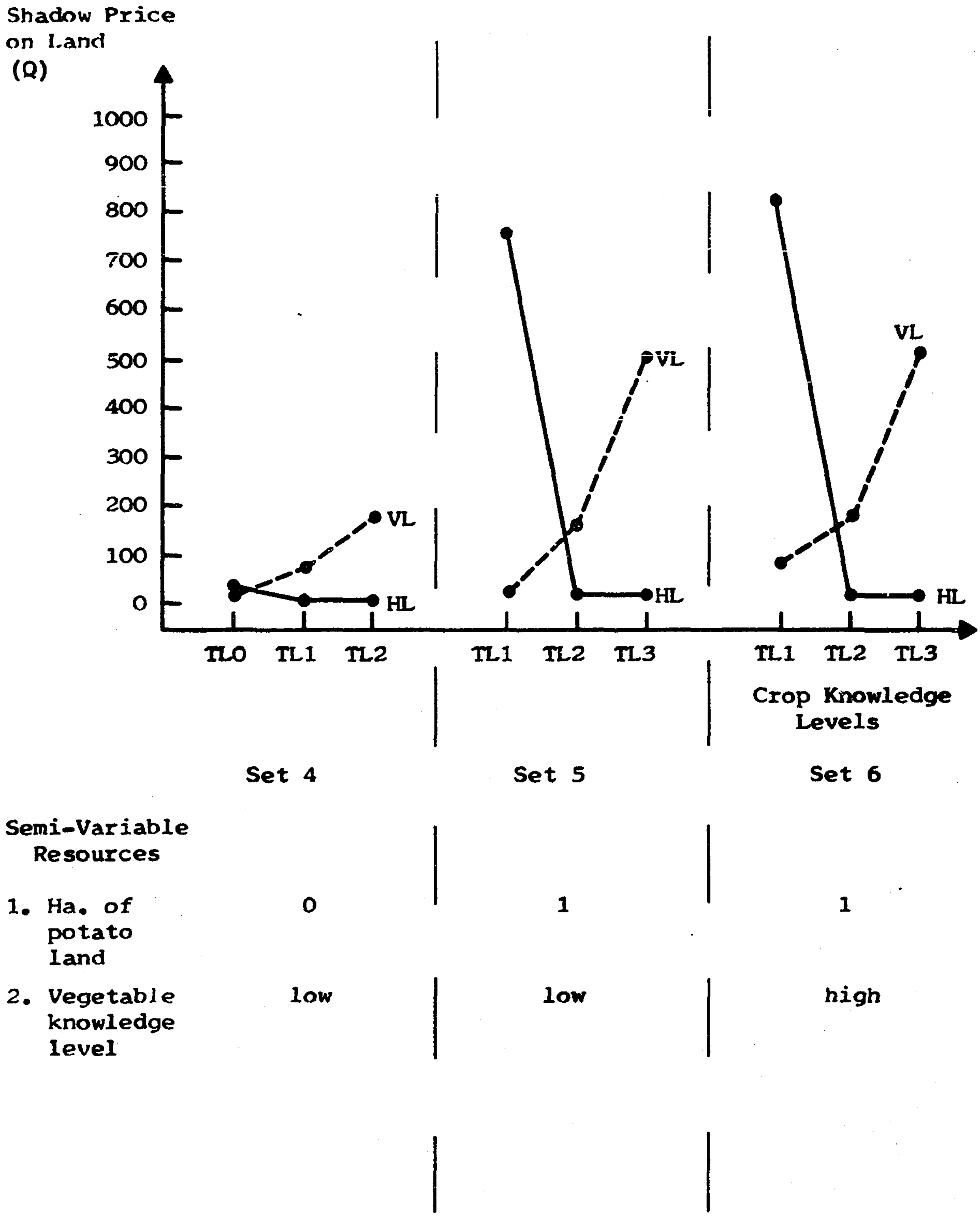


Figure 5.7. Shadow prices for hilly land (HL) and valley land (VL) estimated by solutions in Category 2

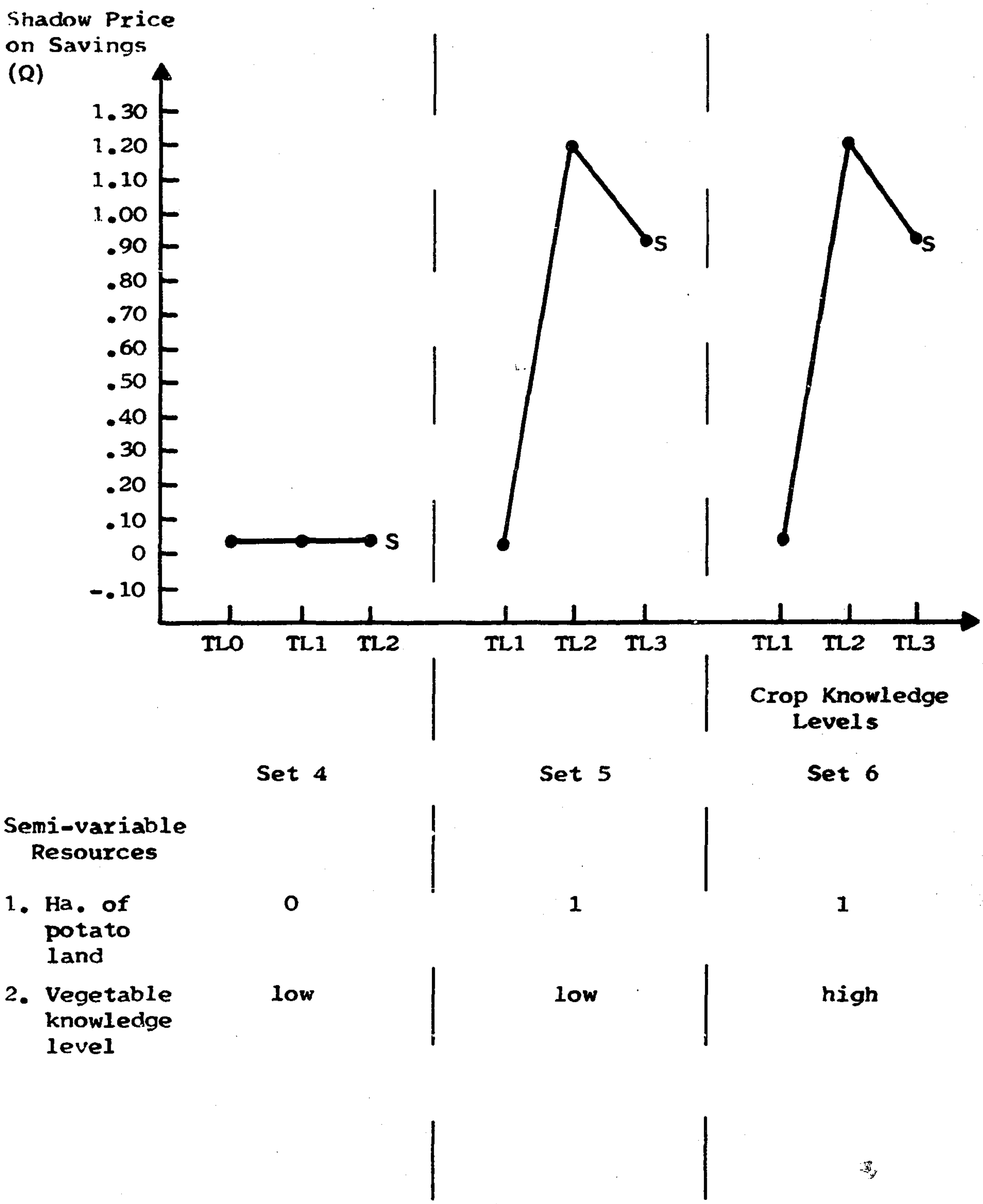


Figure 5.8. Shadow prices for personal savings (S) estimated by solutions in Category 2

Table 5.7. Levels of total and crop income

Type of income	Resource set	TL0	TL1	TL2
Total	1A	443.47	467.69	492.07
Total	1B	447.81	480.91	524.73
Total	4	446.68	478.99	521.96
Crop	1A	106.26	71.99	109.72
Crop	1B	88.63	128.73	181.02
Crop	4	87.50	126.82	178.26

This is not surprising, because both of these resource sets provide the farmer with ample capital and contain identical levels of all other resources. Comparison of the tables in Appendix A reveals that Sets 4 and 1B are also very similar in terms of income earned, shadow price estimates, crops grown, labor hours used, etc.

Figure 5.8 presents estimates for the shadow prices on savings in Set 4. The shadow prices are all Q0.05, reflecting the fact that there is a 5¢ difference between financing production from personal savings versus using Government credit. Government credit is assumed to be available at an interest rate of 10% while savings are charged an opportunity cost of 5%. As was the case in Resource Set 1B where the shadow price on savings was zero, the shadow prices in Resource

Set 4 indicate that the farmer has access to an ample amount of capital. The amount of capital actually borrowed in these three solutions is quite small and ranges from Q22.56 to Q55.31. The amount of capital needed increases as the farmer's level of crop knowledge is expanded.

Figure 5.7 presents estimates for shadow prices on land in Resource Set 4. As was the case for Resource Set 1B, valley land becomes quite valuable when the farmer has a crop knowledge level of TL2. Table 5.8 points out that the shadow prices for Sets 1B and 4 are very similar. The differences between them reflect the 5¢ differential in the cost of acquiring working capital through use of savings versus through the Government credit program.

As was the case in Set 1B, the crops produced in Set 4 are wheat, corn alone and milpa. The amounts of each crop produced are indentical to the amounts produced in the three corresponding solutions of Set 1B. To summarize, the solutions in Set 4 are nearly identical to the solutions in Set 1B. In both of these resource sets, land is the primary restraint; the farmer has an ample amount of capital; and he devotes considerable time to selling labor.

Resource Set 5--Solutions 22, 23, 24

In Sets 2A and 2B, the potato farmer was seriously constrained in his efforts to increase crop income by his limited amount of savings. This situation is changed in Set 5 now that the farmer has access to Government credit. The average level of total income

Table 5.8. Shadow prices on land (Q)

Type of land	Resource set	TLO	TL1	TL2
Hilly	1A	6.02	0.00	0.00
Hilly	1B	30.02	16.32	16.32
Hilly	4	23.78	13.64	13.64
Valley	1A	11.38	41.02	47.96
Valley	1B	15.29	95.19	182.83
Valley	4	14.28	89.04	174.98

for the three solutions in Resource Set 5 is Q1,036.99. This is about Q400 more than average income in Resource Set 2B when he had only Q150 savings to devote to potato production. The average percentage of total income earned from crop production in these three solutions is 69%, indicating that crop production is more important than labor sales in the makeup of total income. Labor sales are still quite important as an income source. The farmer continues to migrate the maximum allowed and earns Q93.20 from migratory labor sales in all three solutions. Local labor sales are also sizeable and average Q228.38. As was the case in solutions for Sets 2A and 2B, the rather large amounts of labor sold locally are due in part to the seasonality associated with potato production and in part to the farmer's shortage of resources which impedes him from growing as many potatoes as his labor supply would allow.

The constraining factors impeding the farmer from further increasing his income in Set 5 are land and capital. In Solution 22 (TL1), the only constraining factor is hilly land because the high yield potato activity the farmer has knowledge of (PHV2) requires 54% hilly land and 46% valley land. Since he has only 50% hilly land and ample amounts of all other resources, the shadow price on hilly land in this solution is quite high, Q764.11. Capital is not a constraint, and the shadow price on savings is Q0.05, because the farmer can borrow as much capital as is needed. The crops grown in Solution 22 are 0.88 hectares of potatoes and 0.12 hectares of wheat.

In Solution 23, the constraining factors are valley land and capital. Valley land is scarcer than hilly land in this solution because the farmer's crop knowledge level has been increased to TL2; now the farmer has knowledge of a new potato production activity (PHV3) which requires 56% valley land and 44% hilly land. Valley land is consequently in relatively short supply, and the shadow price on valley land is Q174.98 per hectare. Capital also becomes scarce in Solution 23. This is because the new potato activity requires more capital. The shadow price on savings rises to Q1.20. Crops grown here are 0.77 hectares of potatoes, 0.07 hectares of corn alone and 0.16 hectares of milpa.

In Solution 24, the farmer's level of crop knowledge is increased to TL3. The constraining factors in this solution are again land and capital. The shadow price on valley land increases sharply to Q514.98. This increase is due to the fact that the farmer has knowledge of another new potato activity. This activity takes place exclusively on valley land (PV4). Thus, valley land is comparatively in greater demand than it was in Solution 23. Since valley land is the more serious of the two constraints, we see a slight dip in the shadow price on savings. The shadow price on savings is only Q0.91 in Solution 24 as compared with Q1.20 in Solution 23; capital is, however, still a significant constraint. The crops produced in Solution 24 are potatoes and milpa.

Even though the farmer has access to Government credit which allows him to borrow up to Q450 for potato production, he has quite a high shadow price on savings in Solutions 23 and 24. The amount of capital borrowed in these three solutions ranges from Q352.14 in Solution 22 to Q468.68 in Solution 23. Another interesting point concerns the composition of crops produced in Resource Set 5. In Solution 22, the farmer grows some wheat, but wheat does not appear in the other two solutions. This is due to the fact that Solution 22 has a knowledge level of TL1 which represents the level of knowledge found among better farmers in 1973. In 1973, wheat was comparatively a more technified crop than corn or milpa due to the efforts of the Gremial Nacional De Trigueros and the Guatemalan Government. A good deal of work has been done with wheat farmers to teach them about new varieties, use of fertilizers and so on. Also, the

Government's support price for wheat has provided farmers with an incentive to adopt the new technologies. Consequently, wheat was a more profitable crop than corn or milpa given the way all three crops were grown by better farmers in 1973. Field trial and demonstration plot results, however, indicate that both corn and milpa are potentially more profitable than wheat. Hence, in Solutions 23 and 24 where farmers are assumed to have knowledge of corn and milpa production activities being used in demonstration trials, the farmer maximizes his income by producing potatoes, corn and milpa instead of potatoes and wheat.

<u>Resource Set 6--Solutions 25, 26, 27</u>

Resource Set 6 is very similar to Set 5. In Set 6, the farmer is assumed to have a high level of vegetable knowledge which allows him to include green onions and carrots among his production alternatives. Including this possibility results in green onions being grown in all three solutions. Total income is increased by an average of Q45.89 compared to total income in Set 5, and income from sale of local labor is decreased by about Q19. Other than these minor changes, everything else is about the same as in Set 5. The shadow prices on savings are identical to those in Set 5. Shadow prices on land are very similar. The amount of borrowed capital in Set 6 increases by about Q17 compared to Set 5. The reader can compare the solutions presented in Appendix A for these two groups to see the extent to which they are alike. Figures 5.6, 5.7, and 5.8 are also helpful in pointing out the similarity which exists for solutions in these two sets. They are so nearly alike that one can effectively sum up the differences between them by saying that in Set 6 the farmer grows onions.

Conclusions to be drawn from Category 2

As was the case in Category 1, the amount of income the family can earn and the constraints which limit the family from earning more income are quite different for farmers who have potato land when compared with farmers who do not have potato land. For example, the average income earned in Set 4 where the farmer could not grow potatoes was Q482.54 while the average income for Sets 5 and 6, in which the family had one hectare of potato land, was Q1059.94. As a result of the essential differences between potato and non-potato farmers, it seems advisable to present the conclusions for each group separately as was done for the solutions in Category 1.

The position which the non-potato farmer in Category 2 finds himself in is virtually identical to the position of the non-potato farmer in Set 1B of Category 1. In both Sets 4 and 1B, the farmer has an adequate amount of capital to finance production but does not have enough land to fully employ the family. The average amount of income earned from crop production is only Q130.86 for the three solutions in Set 4. This is only 21% of average total income. The family needs more land to be able to support itself by farming. Again, one is forced to conclude that the farmer who cannot grow potatoes and who has only one hectare of land is essentially a marginal or a part-time farmer and will only receive marginal benefits from Government programs which provide him with credit or technical assistance.

The potato farmer in Category 2 is in quite a different position. The results of Sets 2A and 5 demonstrate how different his position is. In Set 2A, the average total income for the three solutions was Q496.47. A serious shortage of savings (working capital) was the primary constraint and this shortage was so severe that increasing the farmer's crop knowledge from level TL1 to level TL3 had the effects of bringing about a reduction in the amount of land devoted to potato production, increasing crop income by only Q15.16 and increasing total income by only Q19.93. In Set 5, however, average total income is Q1036.99, an increase of Q540.52 over average total income in Set 2A. Increasing the level of crop knowledge from TL1 to TL3 in Set 5 results in an increase in crop income of Q236.86 and an increase in total income of Q229.11. Obviously, both the Government's crop specific credit program and its extension (or technical assistance) program are capable of helping the potato farmer. In fact, the Government's programs have the potential to help the potato farmer even more. The shadow price on savings of Q1.20 in Solution 23 and of Q0.91 in Solution 24 indicates that if more credit had been available, the farmer would have been able to achieve higher levels of total income and hence could have benefited still more from the Government's credit and technical assistance programs. The fairly high shadow prices on land, however, indicate that land is also becoming a serious constraint in these solutions.

The shadow prices on savings in Solutions 23 and 24 are also important because they point out that the more advanced potato technologies being used by the best potato farmers and on demonstration plots are very capital intensive. The amount of capital which the potato farmer in Category 2 could borrow was fixed at Q450 because this was an average value for potato loans made in 1973. It is an adequate amount to supply the capital requirements of farmers who have a crop knowledge level of TL1, which was the level of knowledge utilized by most potato farmers in 1973. Although the average size loan was adequate to provide the capital required by the average technology in 1973, it is not adequate to finance production activities which become available when the farmer's crop knowledge is increased to levels TL2 or TL3. Level TL2 allows the farmer to adopt a potato production technology which was used by the best potato farmers in 1973 while level TL3 allows the farmer to adopt a technology which was used on demonstration plots in 1973. If the average size loan granted in 1973 should become an upper limit on loan size, it could restrict adoption of the newer potato production activities being introduced by agricultural technicians.

The average level of total income in Sets 5 and 6 is Q1059.94. The average level of crop income is Q747.78, and crop income accounts for about 71% of total income in these solutions. In spite of the facts that shadow prices on land are fairly high in all three solutions and that the shadow price on savings is quite high when the farmer has a crop knowledge level of TL2 or TL3, the shortage of resources implied by these shadow prices has not prevented the potato farmer and his family from potentially earning Q1000 per year. These are, of course, only potential earnings because it is easier to give the farmer capital and knowledge within the context of the model than in the real world, but this result suggests that the Basic Grains Program does have the potential of allowing potato farmers with one hectare of land to reach the Q1000 target level for family income mentioned earlier. This, of course, assumes that input and product prices remain as they were in 1973. To achieve this income, the farmer finds it necessary to borrow an average of about Q440 from the Government. He is still constrained by a shortage of capital in some of these solutions, and he is becoming constrained by a shortage of hilly or valley land depending upon which potato activity he uses. The distinction between hilly and valley land does not mean too much here because the most important distinction with respect to land is that this is potato land. The farmer uses all his land in all six solutions for Sets 5 and 6. He can still increase income somewhat by growing more potatoes instead of corn or milpa if he can obtain working capital for potato production, although the potential for doing this is limited because he already has between 74-91% of his one hectare devoted to potatoes or potatoes and green onions. Further sizeable increases in income will probably only come about by increasing his land holdings. Family labor has been adequate to perform all production activities in these solutions, and a fair amount of labor is sold locally. Local labor sales average about Q220 in these six solutions and migratory labor sales have remained constant at Q93.20 throughout Categories 1 and 2.

The results summarized here indicated that the potato farmer in Category 2 has the potential to benefit substantially from the Basic Grains Program. His income can potentially reach Q1000 per year if he participates in the program, benefits from it and if prices remain as they were in 1973. The major constraint for the potato farmer in Category 2 becomes land, whereas in Category 1 the major constraint was capital. The potato farmer still has a fairly large reserve of labor which could have been devoted to crop production if more land and working capital had been available. Labor sales are still fairly large but are no longer more important than cropping activities as a source of family income. At last the farmer with one hectare of land can be considered primarily a farmer rather than a laborer.

Presentation of Resource Sets in Category 3

Two changes have been made in the farmer's set of semi-fixed resources in Category 3. The first and most important of these changes is the expansion of the farmer's land holdings from one hectare to three hectares. The second change is to assume that the family is unable to hire local labor to assist with cropping activities. This assumption is made to investigate the seriousness of any seasonal shortages of labor which might exist on the larger three hectare farm. It will be relaxed in Category 4 so that we may compare the farmer's relative positions when he is allowed to hire ten laborers in every quarter and when he must rely exclusively on family labor for cropping activities. The other semi-fixed resources remain at the same levels as in Category 2. They are: availability of credit through the Government sponsored crop specific credit program and Q50 savings which can be allocated to crop production.

The semi-variable resources in Category 3 are the same as in Category 2. They are: (1) the level of vegetable knowledge; and (2) the amount of potato land. The level of vegetable knowledge continues to take on the values high and low as in Categories 1 and 2. Potato land is allowed to take on three possible levels: zero hectares, one hectare and three hectares. The pattern of presenting solutions for different levels of the variable resource, crop knowledge, is unchanged. When the farmer has no potato land, solutions will be calculated for the three levels of crop knowledge TL0, TL1, and TL2. When the farmer does have potato land, optimal solutions will be calculated for the levels TL1, TL2, and TL3. Table 5.9 specifies the levels which potato land, vegetable knowledge and crop knowledge will take in each resource set and in each solution.

Resource Set 7--Solutions 28, 29, 30

In Resource Sets 1A and 4 of Categories 1 and 2 respectively, the effectiveness of agricultural credit and technical assistance programs as instruments for helping non-potato farmers was investigated.

Table 5.9. Resource sets in Category 3

Resource set	Optimal solution number	Number of hired laborers	Hectares of potato land	Level of vegetable knowledge	Crop knowledge level
7	28	0	0	low	TL0
7	29	0	0	low	TL1
7	30	0	0	low	TL2
8	31	0	1	low	TL1
8	32	0	1	low	TL2
8	33	0	1	low	TL3
9	34	0	1	high	TL1
9	35	0	1	high	TL2
9	36	0	1	high	TL3
10	37	0	3	high	TL1
10	38	0	3	high	TL2
10	39	0	3	high	TL3

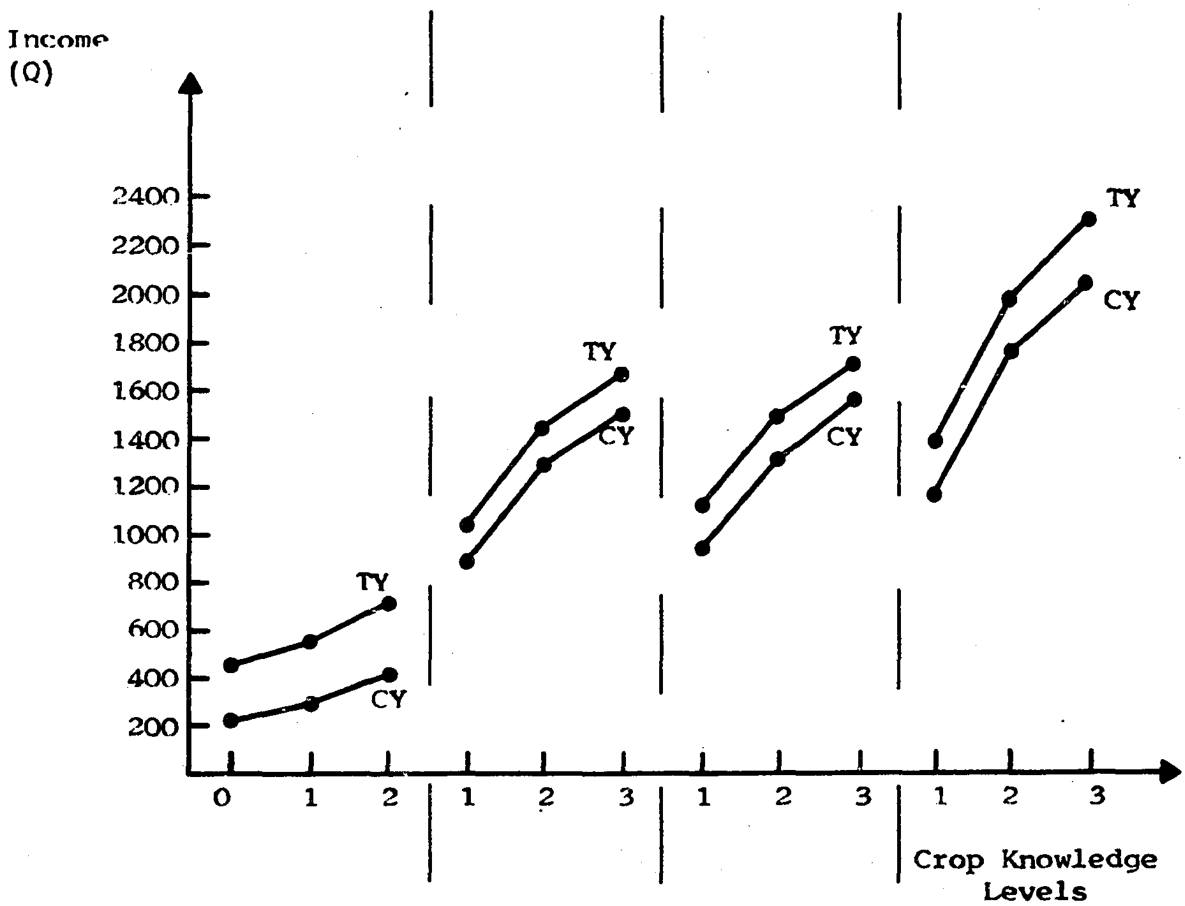
The results from those solutions indicated that these instruments were not particularly effective because the farmer and his family were obliged to spend most of their time working off the farm. The farmer did not have enough land to make a living from farming and could best be considered as a part-time or marginal farmer.

In Resource Set 7, the non-potato farmer has been given more land. He now has 1.5 hectares of hilly land and 1.5 hectares of valley land. This is one hectare more of both hilly and valley land than he had in Categories 1 or 2. The farmer in Set 7 is not allowed to hire local labor to assist with cropping activities, but with these two exceptions, his other resources are the same as they were in Set 4.

The effects of these changes upon the levels of cropping and total income are quite interesting. The average amount of total income earned in Set 7 is Q584.53. This is an increase of Q101.98 over the average total income earned in Set 4. It is both interesting and reassuring to note that in each of the three solutions in Set 7, the level of total income is very close to the sum of the level of total income specified in the corresponding solution of Set 4 and the amount estimated for the shadow prices on hilly and valley land. For the three solutions in Set 7, the total income estimated by the model is between Q2.62 and Q12.50 of the income estimated in Set 4 plus the estimated shadow prices on land in Set 4. For example, the income estimated in Solution 19 of Set 4 (in which the farmer has a crop knowledge level of TLO) is Q446.68.

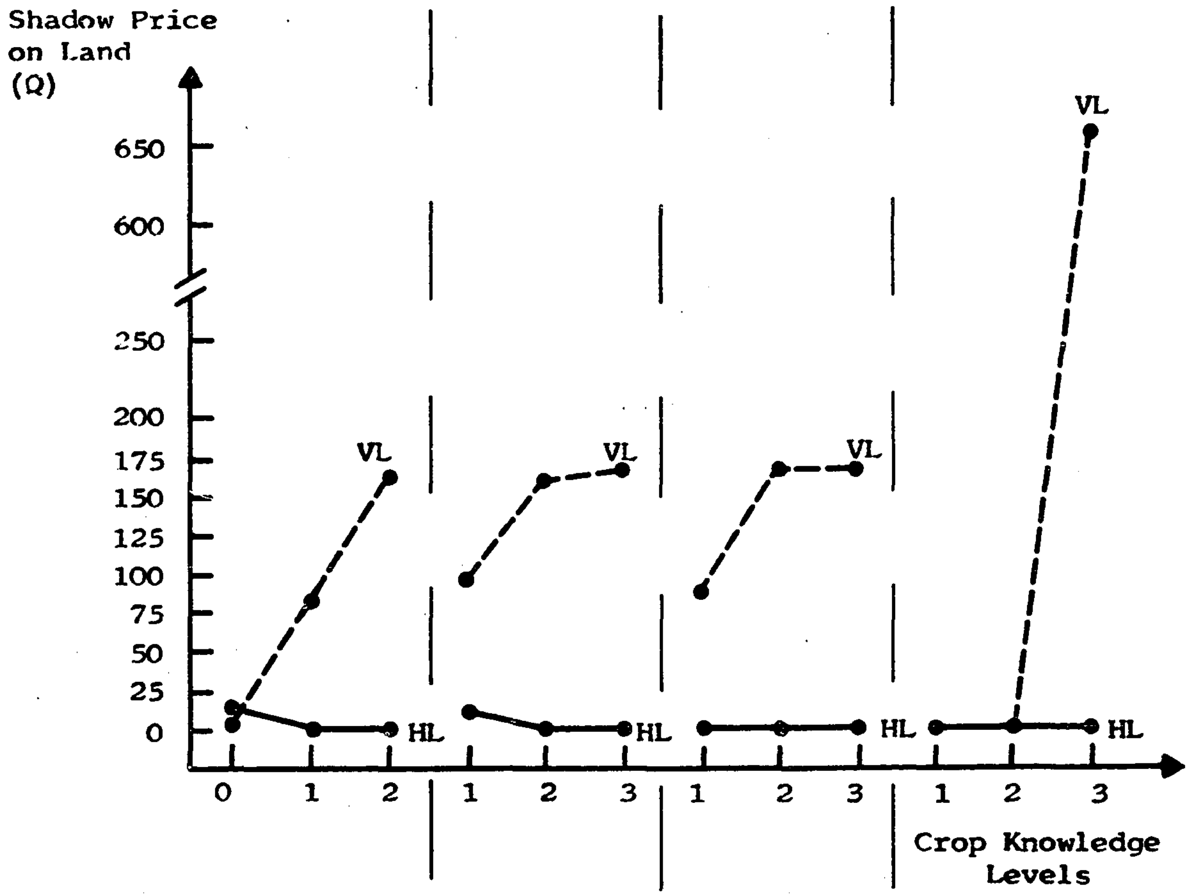
The shadow prices on hilly and valley land are Q23.78 and Q14.28. These sum to Q484.74 which is only Q2.62 more than the amount of total income specified in Solution 28 of Set 7 (in which the farmer similarly has a crop knowledge level of TLO). The fact that the income estimates in Set 7 come this close to the estimates in Set 4 substantiates our earlier conclusion that land was the only serious constraint limiting the farmer's ability to increase income in Set 4. The relationship of crop income to total income in Category 3 can be seen in Figure 5.9. Crop income is about 54% of total income in Resource Set 7. This is the first set of solutions in which the non-potato farmer has earned a higher percentage of income from selling crops than from selling labor. Crop income should constitute an even higher percentage of total income in Category 4 when the farmer is allowed to hire local labor to relieve the present fourth quarter labor shortage.

The primary constraints limiting income in Set 7 are land and fourth quarter labor. The shadow price on savings of only Q0.05 in all three solutions indicates that although more savings are to be preferred to less, capital is not a constraint in any of these solutions. Shadow prices on land in Category 3 are presented in Figure 5.10. The shadow prices for Set 7 in Figure 5.10 show much the same type of pattern observed in Set 4. Increases in the farmer's amount of crop knowledge have the effect of increasing the shadow price on valley land. When the level of crop knowledge is increased from TLO to TL2, the shadow price on valley land increases from Q3.70 to



	Set 7	Set 8	Set 9	Set 10
Semi-variable Resources				
1. Ha. of potato land	0	1	1	3
2. Vegetable knowledge level	low	low	high	high

Figure 5.9. Levels of total income (TY) and crop income (CY) estimated by solutions in Category 3



	Set 7	Set 8	Set 9	Set 10
Semi-variable Resources				
1. Ha. of potato land	0	1	1	3
2. Vegetable knowledge level	low	low	high	high

Figure 5.10. Shadow prices for hilly land (HL) and valley land (VL) estimated by solutions in Category 3

Q164.45 per hectare. This shadow price of Q164.45 per hectare suggests that if the farmer were given another hectare of valley land, he would curtail either some of his milpa production or some of his fourth quarter sales of migratory labor and use the additional valley land for crop production activities, thus increasing his total income. The shadow price on valley land in Set 7 is nearly as high as it was in Set 4, indicating that even though the farmer has a total of three hectares of land, shortage of valley land continues to be the most serious constraint in the model.

Fourth quarter labor is also a constraint in these solutions, although it is not a very serious one. The farmer continues to sell the maximum amount of migratory labor allowed by the model even though a shortage of fourth quarter labor constrains his crop production activities. When the farmer has a crop knowledge level of TL0, the shadow price on one hour of hired labor in fourth quarter is Q0.023. When his crop knowledge is increased to level TL1 or TL2, the shadow price on hired labor rises to Q0.026. A shadow price of Q0.023 or 2.3¢ per hour means that if the farmer could have hired an additional hour of local labor, that hour would have allowed him to achieve a gross increase of 9.9¢ in total income (9.9¢ minus the hourly wage of 7.6¢ equals 2.3¢). This also means that his own last hours used in crop production activities in fourth quarter were worth at least 9.9¢ per hour. As was pointed out, this is not a high enough return to induce him to curtail migratory labor sales activities which earn 11¢ per hour, but a return to crop production of 9.9¢ per hour is fairly close to the wage he could earn as a migratory laborer. This is a significant result because it provides two important pieces of information. First, even when the farmer has only a crop knowledge level of TLO, fourth quarter labor hours spent on crop production are returning 9.9¢ per hour which is almost as much as the farmer earns as a migratory laborer. This lends support to the idea that workers migrate because they are unemployed rather than because the wage paid to migratory laborers is significantly greater than the return to labor from crop production activities on their own farms. Second, increasing the farmer's level of knowledge to TL1 or TL2 increases the value of the farmer's labor from 9.9¢ per hour to 10.2¢ per hour. This increase comes about even though the farmer is using part of his labor on cropping activities which require only traditional crop knowledge (TLO). He does this because he has an excess amount of hilly land which in the model can only be used with traditional technologies. If the farmer could use the money he borrows from the Government to adopt more capital intensive high yield technologies on hilly lands as well as on valley lands, then the return to labor from cropping activities would probably rise even more. As farmers learn of new capital intensive production activities which can be used on hilly as well as on valley lands, the return to an hour of fourth quarter labor spent on crop production could rise well above 11¢ per hour. Thus, one effect of the Government's technical assistance program would be to increase the value of labor hours spent in crop production activities. This might cause local wages to rise if in the aggregate there is either a seasonal or year-round shortage of labor and if this shortage is not overcome by increased mechanization. Should local wages rise above 11¢ per hour, there might be some competition between local labor demands and migratory labor demands for the small farmer's labor. If local wages did rise, the small one hectare farmer considered earlier in Categories 1 and 2 would achieve indirect benefits from technical assistance programs through the higher agricultural labor wage levels even though his land holdings were too small to allow him such benefits from adoption of new technologies on his own farm.

The crops produced in Set 7 are wheat, corn and milpa. With a knowledge level of TL0, the farmer produces 71% wheat, 28% corn alone and 1% milpa. When crop knowledge is increased to level TL1, he produces 50% wheat (on his valley lands), 30% milpa and allows the rest of his land to lie fallow, because he is short on labor and the return from selling migratory labor is greater than the return from using labor to grow crops on hilly lands. When crop knowledge is increased to TL2, he discontinues wheat production and instead produces 50% corn alone (on his valley land) and 19% milpa allowing the rest of the land to lie fallow.

<u>Resource Set 8--Solutions 31, 32, 33</u>

In Resource Set 8, the farmer has one hectare of land suitable for potato production and three hectares of land in total. These results are essentially a continuation of the results discussed earlier in Set 5 of Category 2. In Set 5, the farmer's main constraints had been land and capital. Both of these constraints have been eased considerably with the result that average total income for the three solutions in Set 8 is increased by Q354.19 over average total income in Set 5. As was seen in Figure 5.9, crop income constitutes about 89% of total income in Set 8. Local labor sales have been considerably reduced and average only about Q66 although migratory labor sales remain constant at Q93.20 throughout these three solutions.

The constraints in Set 8 are again land and hired labor. The most serious of these is the constraint on potato land. The shadow price on another hectare of potato land averages Q722.30 for the three solutions. Figure 5.10 summarizes the shadow price estimates for hilly and valley land. The pattern observed in Figure 5.10 is a familiar one. The shadow price on valley land is higher than the shadow price on hilly land and increases with the farmer's level of crop knowledge. The farmer does not use all his hilly land when he has a crop knowledge level of TL2 or TL3, and, consequently, the shadow price falls to zero for those two solutions. As was the case in Set 7, a shortage of hired labor is responsible for the farmer not being able to use all his hilly land. In Set 7, the shortage of local hired labor was in fourth quarter. In Set 8, the shortage is in fourth quarter for crop knowledge level TL2 and in second quarter for level TL3. The farmer has devoted all the labor he and the family have in the second quarter to crop production and the amount was insufficient. Since no migratory labor sales are allowed in second quarter, the shortage of second quarter labor cannot be attributed to migratory labor sales.

The crops produced in Set 8 follow the same pattern seen earlier. Potatoes, wheat and milpa are produced when the farmer has crop knowledge level TL1. Potatoes, corn alone and milpa are grown when crop knowledge is increased to levels TL2 and TL3.

Resource Set 9--Solutions 34, 35, 36

Resource Set 9 adds a high level of vegetable knowledge to the resources considered in Set 8. Addition of the high level of vegetable knowledge causes two changes in the solutions: (1) an increase in the average level of total income; and (2) inclusion of one cuerda of onions among the crops produced. The average level of total income increases by Q50.42. This increase is due to an average increase in crop income of Q33.83 and an average increase in local labor sales income of Q16.59. Local labor sales are increased because the cuerda of onions requires less labor than the crops it displaces. As can be seen from Figure 5.9, crop income is again a high percentage of total income. Local labor sales now account for only about 5½% of total income. Migratory labor sales remain constant at Q93.20 throughout Set 9 and constitute about 6½% of average total income leaving about 88% of total income to be accounted for by crop sales.

The major constraints in Set 9 are potato land, valley land, vegetable knowledge and local hired labor. Potato land has an average shadow price of Q707.33. The shadow price on valley land averages only Q138.56. This difference reflects the fact that the important constraint is the climatic and agronomic appropriateness of the land for use in potato production rather than the land itself. The shadow price on hilly land is zero in all three solutions. The farmer is not able to use all his hilly land due to a shortage of second quarter labor. The shadow price on one hour of second quarter labor is Q0.036 in all three solutions. This means that an hour of second quarter labor could add Q0.112 or 11.2¢ per hour to gross income if it could be hired and, consequently, that the farmer's last hours devoted to crop activities in second quarter are earning at least 11.2¢ per hour. The average shadow price on vegetable knowledge of Q49.03 indicates that if the farmer had one more cuerda of land suitable for vegetable production, he could increase his total income about Q50 by growing more vegetables. This shadow price is on vegetable knowledge but could have been on vegetable land because the two are tied together. The farmer is given only one cuerda of vegetable land and also only enough knowledge to allow him to produce vegetables on that one cuerda.

The composition of crops produced is very similar to the crops produced in Set 8 except that one cuerda of green onions is produced in each solution of Set 9. Solution 34 with a crop knowledge level of TL1 produces one cuerda of onions, one hectare of potatoes, 1.02 hectares of wheat, and 0.74 hectares of milpa. When the level of crop knowledge is increased to TL2 and TL3, the farmer continues to grow a cuerda of onions, a hectare of potatoes, and under a hectare of milpa, but he does not grow wheat. Instead, corn alone is grown. The amounts of corn alone and milpa grown in these two solutions are altered with respect to the amounts grown in the corresponding solutions of Set 8 as a result of including a cuerda of onions among the crops produced and also as a result of the shortage of second quarter labor.

Resource Set 10--Solutions 37, 38, 39

In Resource Set 10, the farmer's level of potato land is increased to three hectares. He continues to have a high level of vegetable knowledge, but due to the extreme shortage of second quarter labor, no green onions are grown (onions require a fairly large amount of second quarter labor). The only crop grown in these solutions is potatoes. Average total income for the three solutions in Set 10 is Q1882.10, an increase of Q490.93 over average total income in Set 8 where only one hectare of potatoes and no vegetables are grown. Crop income is about 88% of total income.

The most important binding constraint here is second quarter labor. The shadow price on hired labor in second quarter ranges between Q0.66-Q1.17 per hour. This extremely high shadow price for farm labor on the altiplano of western Guatemala indicates that the particular combination of resources specified in Set 10 has lost touch with reality. For this reason, the results are only presented briefly. The interested reader may refer to Table A13 for more information on these solutions.

<u>Conclusions for the non-potato farmer in Category 3</u>

In Category 2, the most serious constraint for the non-potato farmer was land--particularly valley land. The non-potato farmer with a crop knowledge level of TL2 was able to earn Q521.96 total income in Category 2. In Category 3 with another hectare of hilly land and another hectare of valley land, the farmer with a crop knowledge level of TL2 is able to earn Q698.09, an increase of Q176.13. This increase is achieved by using his entire 1.5 hectares of valley land and 0.58 of his 1.5 hectares of hilly land. This means that 92% of the additional hectare of hilly land is not used because of a shortage of fourth quarter labor. Three important conclusions can be drawn from this information.

First, the fact that the farmer did not use 0.92 hectares of his hilly land indicates that a family with a labor supply equivalent to 2.1 farm laborers will begin to experience shortages of labor as farm size approaches three hectares. As was mentioned earlier, the return to the last hour which the farmer devoted to crop production in fourth quarter was estimated to be between 9.9¢ and 10.2¢ depending upon the farmer's level of crop knowledge. This was not a high enough return to allow crop production to compete with migratory labor sales for the farmer's fourth quarter labor, but it is getting close to the migratory labor wage of 11¢ per hour. If the farmer had used the 416 hours which were sold as fourth quarter migratory labor for milpa production on hilly land, he could have produced about an additional 0.83 hectares of milpa. If this had been done, approximately 1.41 of the 1.5 hectares of hilly land would have been used for crop production. The farmer and his family would not have been able to farm their entire three hectares of hilly and valley land, but they would have been able to use 97% of it. Thus, it appears that for a family with a total labor supply equivalent to 2.1 adult male farm laborers, three hectares approximate an upper limit for farm size if the family is to do all the work itself without turning to mechanized production methods.

A second important conclusion relates to the fact that the family did not use all its hilly land in Solutions 29 and 30. As was mentioned earlier, this was due to the shortage of fourth quarter labor, but it is also due to the fact that an activity such as milpa on hilly land uses a very low level of technology or crop knowledge (level TLO in this model). If data were available on capital intensive production practices for use on hilly lands (such as we have on valley lands), it seems likely that hilly land activities could compete with migratory labor sales activities for the farmer's time and that incomes earned from crop production on hilly lands would approach the levels of income earned on valley lands. It is very important that this data be collected, because Table 2.4 pointed out that 76.2% of arable highland in the nine highland departments is poorer hilly land. Until information becomes available on the yield effect of employing capital intensive production practices on hilly land, it will continue to be difficult to estimate the amount of income the farmer can earn on a farm composed of both hilly and valley land.

The third conclusion relates to the level of income the farmer earns. In Set 7, the farmer has three hectares of land to use for crop production. In Solution 28 with a crop knowledge level of TLO, he uses all three hectares but can earn a total income of only Q482.12. As his crop knowledge is increased, his total income goes up, but his use of hilly land declines due to the shortage of fourth quarter labor and the relatively low returns from farming hilly land. For example, in Solution 30 with a crop knowledge level of TL2, the farmer's total income is Q698.09, but he uses only 0.58 hectares of his hilly land. The only serious constraint in Solution 30 is the shortage of valley land (he could divert labor from migratory labor sales), but even if the farmer had another hectare of valley land, its shadow price of Q164.45 suggests that total income would not be more than Q862.54. With two more hectares of valley land, the farmer might be able to increase his income to the target level of Q1000 per year. Now let us assume that hilly lands, although naturally poorer, were capable of producing yields comparable to the yields estimated for valley lands in this study. Since the farmer in Set 7 does not use almost one hectare of hilly land, it is plausible to expect that total income could be increased by about Q165 (the value of the shadow price on valley land in Solution 30) if the farmer were able to use this hilly land with new capital intensive crop production technologies. These technologies would be similar to the technologies used in the model on valley lands which require a crop knowledge level of TL2. Use of hilly land in this way would raise total income for the non-potato farmer in Category 3 to about Q860. If the farmer were then given an additional hectare of land which might be composed of 50% hilly and 50% valley land, it appears likely that his level of total income might reach the targeted Q1000 per year. This means that to increase income to Q1000, the farmer needs: (1) a crop knowledge level of TL2 which would enable him to achieve yields on hilly and valley lands that would be comparable to the yields achieved on demonstration plots in 1972 and 1973; (2) Government credit; and (3) a total of four hectares of land. Yet, in Chapter 2 it was estimated that given the present amounts of good and poor land and the present rates of population growth, a family of four in the year 2000 would have a farm of only 1.68 hectares, and only 0.40 hectares of this would be what has been classified as good valley land. Thus, the results in Category 3 suggest to us that it will not be possible for farmers to earn Q1000 from 1.68 hectares. Non-potato farmers would need more than twice this amount of land to reach the target level of income given present price levels and present levels of technology used on demonstration plots. Category 3 estimates that the farmer would probably not be able to earn more than Q700 from 1.68 hectares of valley land, and only about Q450 of this would be from sale of crops. It does not appear as through the non-potato farmer in the year 2000 will be able to earn Q1000 per year unless there are: (1) major breakthroughs in cropping technologies; (2) increases in prices of corn, beans, and wheat; or (3) increases in farm size.

Conclusions for the potato farmer in Category 3

The solutions in Sets 8, 9, and 10 of Category 3 deal with the farmer who does have potato land. These solutions are interesting because they show that potential income for the potato farmer reaches heights which are really quite remarkable when compared to the levels of potential income earned by non-potato farmers. This is not a new or surprising insight because the income potential from potato production was made apparent in Categories 1 and 2. The only new information which Category 3 reveals is that potato farmers, like non-potato farmers, are faced with a seasonal labor shortage when they are given three hectares of land and are not allowed to hire local labor. We saw earlier in our discussion of non-potato production that the farmer experienced a shortage of fourth quarter labor. This is because labor demands tend to be particularly high in fourth quarter for wheat, corn, and milpa production. This shortage also appears in one solution of Set 8, but the more serious period of labor shortage for potato farmers is second quarter. Seven out of the nine solutions in Sets 8, 9, and 10 show that second quarter is the time when the shortage of labor is most restrictive. The shadow prices on second quarter hired labor range from Q0.026 to Q1.17, indicating that in some of these solutions the shortage of second quarter labor is very severe. Table 5.10 presents information

Table 5.10. Shadow prices on hired labor

Resource set	Solution	Quarter of shortage	Shadow price	Hectares of potato land
7	28	4th	0.023	0
7	29	4th	0.026	0
7	30	4th	0.026	0
8	31	None	0.000	1
8	32	4th	0.026	1
8	33	2nd	0.036	1
9	34	2nd	0.036	1
9	35	2nd	0.036	1
9	36	2nd	0.036	1
10	37	2nd	0.713	3
10	38	2nd	1.170	3
10	39	2nd	0.660	3

concerning shadow prices on local hired labor in Category 3. Table 5.10 shows us that the most severe shortages of hired labor are in Set 10 where the farmer has three hectares of potato land. Again, the amount of potato land the farmer is given overshadows other variables. Since this is the case, let us briefly review and contrast the solutions for potato farmers with one hectare of potato land against the solutions for farmers with three hectares of potato land.

Farmers with one hectare of potato land were analyzed in Sets 8 and 9. These farmers earned an average total income of Q1416.39 which is Q831.86 more than the average total income earned by non-potato farmers in Category 3. Crop income for potato farmers with one hectare of potato land was about 88% of total income and averaged well over Q1000. The crops produced included potatoes and milpa in all six solutions. In those solutions where the farmer was assumed a crop knowledge level of TL1, wheat was also produced. Where the farmer was assumed to have a crop knowledge level of TL2 or TL3, corn alone replaced wheat. Onions were produced in all three solutions of Set 9 where the farmer was given a high level of vegetable knowledge. While hired labor was in short supply in five of these six solutions, it was not in critically short supply. The shadow prices on local hired labor for this group range from Q0.00 to Q0.036 per hour. The only restraints other than hired labor are potato land and valley land. Shadow prices on an additional hectare of potato land average about Q715. Shadow prices on valley land range between Q83.05 and Q166.32. If more valley land were made available, it would probably be used for additional production of wheat and corn alone. Since labor is scarce in some of these solutions, the labor needed for production of wheat or corn alone on valley land would probably be made available by decreasing milpa production on hilly land.

The farmer with three hectares of potato land has an average total income of Q1882.10. This is Q465.71 more than average total income for farmers with one hectare of potato land and Q1297.57 more than for farmers with no potato land. Crop income for farmers with three hectares of potato land is again about 88% of total income. The only crop produced in Set 10 is potatoes. Even though the farmer is assumed to have a high level of vegetable knowledge, no green onions are grown. This is due to the fact that green onions require a considerable amount of second quarter labor, and second quarter labor is in very short supply. The shadow price on second quarter labor ranges from Q0.713 to Q1.17. The only constraint other than second quarter labor is a shortage of valley land in Solution 39. More valley land could be used in this solution because the most advanced method of potato production in the model requires 100% valley land. The farmer has a crop knowledge level of TL3 and, therefore, has knowledge of this advanced method.

Presentation of Resource Sets in Category 4

In Category 4, the number of laborers that may be hired in any given quarter is increased from zero to ten. All other resources remain as they were in Category 3. Consequently, the semi-fixed resources in Category 4 are: three hectares of land; access to Government-sponsored crop specific credit program; Q50 personal savings; and availability of ten hired laborers to assist with cropping activities. The semi-variable resources are: two levels of vegetable knowledge and three levels of potato land. Crop knowledge continues to be the variable resource. As in Categories 1, 2, and 3, the resources have been divided into several sets; these sets are presented in Table 5.11.

The method of presenting results will follow the same pattern established in the first three categories with one minor exception. Resource Set 14 will not be discussed in the text. The solutions in Set 14 are quite similar to those in Set 15, and the degree to which they differ is approximated quite well by the differences between Sets 12 and 13. Consequently, it was decided that a discussion of Set 14 in the text was not necessary. The solutions for Set 14 are, however, included in Appendix A.

Resource Set 11--Solutions 40, 41, 42

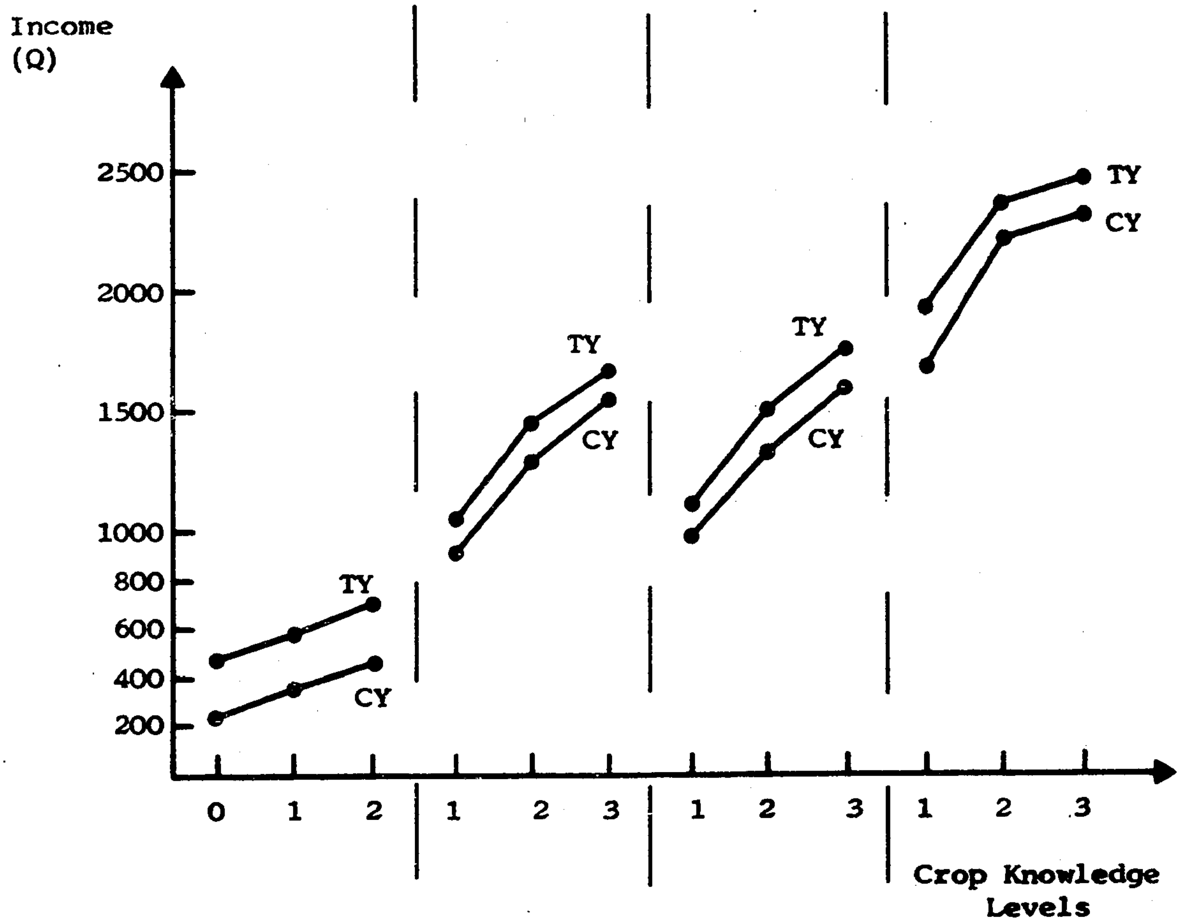
In Resource Set 11, the non-potato farmer with a low vegetable knowledge level has been allowed to hire up to ten men in any quarter to assist with crop production activities. This is a continuation of the results presented in Set 7 of Category 3 in which the farmer was not allowed to hire any men to assist with crop production activities. All other resources in Sets 7 and 11 are identical. The reader will recall that one of the conclusions made with regard to the solutions in Set 7 was that although fourth quarter labor was a constraint, it was not a very serious one. This conclusion is borne out in the solutions of Set 11. Allowing the farmer to hire local labor results in an average of only 26 days' labor being hired

Table 5.11. Resource sets in Category 4

Resource sets	Optimal solution number	Hectares of potato land	Level of vegetable knowledge	Crop knowledge level	Number of hired laborers
11	40	0	low	TL0	10
11	41	0	low	TL1	10
11	42	0	low	TL2	10
12	43	1	low	TL1	10
12	44	1	low	TL2	10
12	45	1	low	TL3	10
13	46	1	high	TL1	10
13	47	1	high	TL2	10
13	48	1	high	TL3	10
14	49	3	low	TL1	10
14	50	3	low	TL2	10
14	51	3	low	TL3	10
15	52	3	high	TL1	10
15	53	3	high	TL2	10
15	54	3	high	TL3	10

in fourth quarter, the only quarter in which labor is hired.

Figure 5.11 presents information on total income and crop income earned in Category 4. The pattern of total and crop income presented here is quite similar to the pattern observed in Category 3. The amount of total income earned in Set 11 is increased by an average of only Q5.41 over average total income in Set 7. This increase is caused by an average increase in crop income of Q38.88 and an average decrease in labor sale income of Q33.47. The percentage of total income earned from sale of crops is 60% in Set 11 as compared with 54% in Set 7. Migratory labor sales remain constant at Q93.20 throughout both Sets 7 and 11. The primary effect of allowing the farmer to hire local labor has been to slightly increase the amount of income earned from cropping activities and slightly decrease income earned by selling labor. The increased amount of income earned from cropping activities results from two types of changes. With a crop knowledge level of TL0, the farmer alters the crops he grows so that his main crops are wheat and milpa rather than the wheat and corn alone which were grown in the corresponding solution of Category 3. When the level of crop knowledge is increased to TL1 in Category 4, the farmer continues to produce wheat and milpa (just as he did in Category 3), but the availability of hired labor in Category 4 allows the farmer to increase the amount of land he farms, and he increases his production of milpa from 0.89 hectares in Category 3 to 1.5 hectares in Category 4. Similarly, when the farmer is given a crop knowledge level of TL2 in Category 4, he

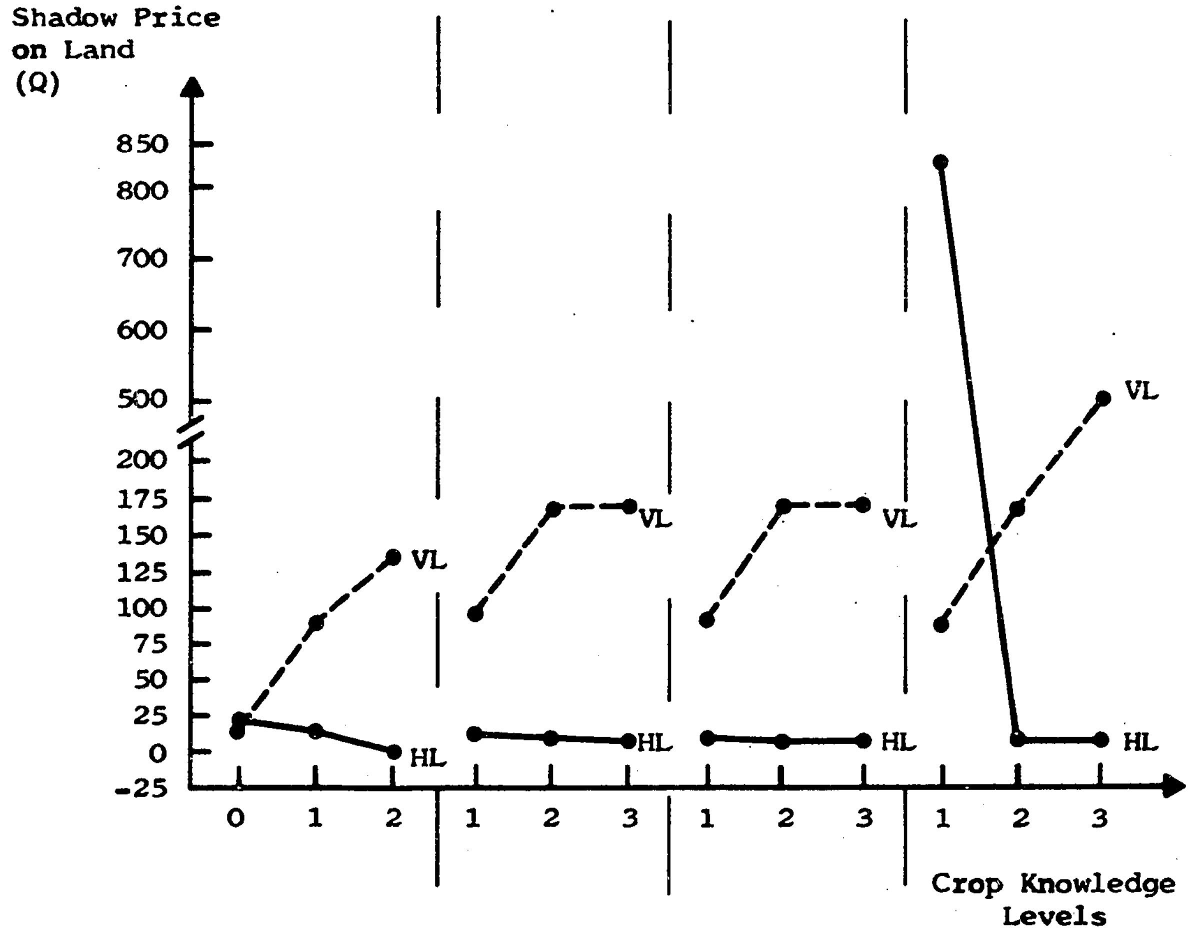


	Set 11	Set 12	Set 13	Set 15
Semi-variable Resources				
1. Ha. of potato land	0	1	1	3
2. Vegetable knowledge level	low	low	high	high

Figure 5.11. Levels of total income (TY) and crop income (CY) estimated by solutions in Category 4

continues to produce corn alone and milpa (as he did in Category 3), but he increases his production of milpa from 0.58 to 1.02 hectares.

The main constraint preventing the farmer in Set 11 from increasing his income is land. Shadow prices on land are presented in Figure 5.12. The pattern observed in Figure 5.12 for Set 11 is a familiar one. The shadow prices on both hilly and valley lands are fairly low when the farmer has a crop knowledge level of TL0. As the level of crop knowledge is increased, shadow prices on valley land rise and shadow prices on hilly land fall. The shadow price on hilly land remains positive in Solutions 40 and 41 but falls to zero in Solution 42. This drop in the shadow price for hilly land in Solution 42 is caused by a shortage of capital which prohibits the farmer from using all his hilly land. Capital becomes a constraint because the model allows the farmer to borrow a maximum of Q240 for production of corn alone and milpa on a three hectare farm. One of the corn alone activities in Solution 42 requires inputs totaling Q157.06 per hectare which is almost double the Q80 per hectare maximum specified in the model. The limit of Q80 per hectare for corn alone and milpa production loans was adopted because the average size loan approved by BANDESA in 1973 was just under Q80 per hectare. This is an adequate amount to finance production of corn alone or milpa with a crop knowledge level of TL0 or TL1 but not with a crop knowledge level of TL2, the level that was used on demonstration plots in 1973. This points out the need



	Set 11	Set 12	Set 13	Set 15
Semi-variable Resources				
1. Ha. of potato land	0	1	1	3
2. Vegetable knowledge level	low	low	high	high

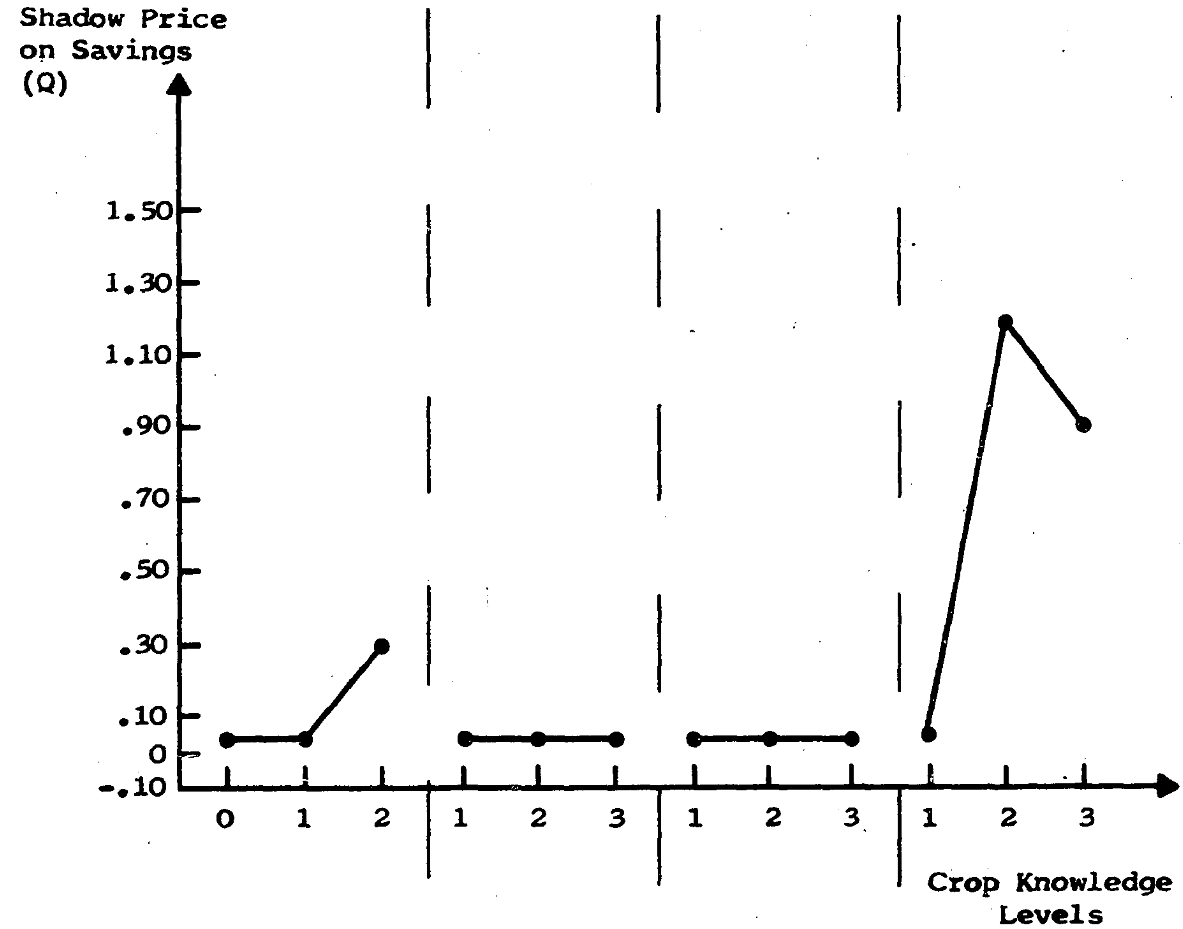
Figure 5.12. Shadow prices for hilly land (HL) and valley land (VL) estimated by solutions in Category 4

for increasing the authorized amounts for loans in the future. It is expected that farmers will be adopting newer capital intensive technologies and that the level of crop knowledge used on demonstration plots in 1973 will be widely used by better farmers in 1980. Figure 5.13 graphically illustrates the relationship which exists between adoption of new technologies and shadow prices on savings in Category 4.

Resource Set 12--Solutions 43, 44, 45

The set of production possibilities presented in Set 11 is enlarged upon in Set 12 by specifying that one of the three hectares of land in Set 11 is suitable for potato production. The result is the usual one. One hectare of potatoes is grown in each solution of Set 12.

The solutions in Set 12 are very similar to the solutions in Set 8 of Category 3. This is to be expected since the two groups share a common resource base save for the amount of labor which may be hired. Although the farmer in Set 12 is allowed to hire up to ten men in every quarter, very little labor is hired. In Solution 43, no labor is hired and the solution is identical to Solution 31 of Set 8 in Category 3. In Solution 44, the only labor hired is 22 hours in the fourth quarter. In Solution 45, the farmer hires 73 hours in fourth quarter and 58 hours in second quarter. This adds to a total of only 153 hours for all three solutions. That so little labor is hired in Set 12 is a testimony to the complementarity which exists between potato production and other activities



	Set 11	Set 12	Set 13	Set 15
Semi-variable Resources				
1. Ha. of potato land	0	1	1	3
2. Vegetable knowledge level	low	low	high	high

Figure 5.13. Shadow prices for personal savings (S) estimated by solutions in Category 4

in the model. This complementarity results because potatoes require their largest labor input in second quarter while corn alone, milpa and wheat require the most labor in fourth quarter. Migratory labor sales in third and fourth quarters are also quite complementary with potato production. This complementarity allows the farmer who produces potatoes in combination with milpa, corn alone, or wheat to have a more balanced quarterly labor demand schedule and results in there being very little difference between solutions in which the farmer can hire ten men and solutions in which the family must do all the work itself. For example, the difference between average total income for Sets 8 and 12 is only Q1.20.

The farmer in Set 12 is in quite an enviable position compared to many of his neighbors. He earns between Q1052.07 and Q1671.14 depending upon his level of crop knowledge. His income from sale of crops is between Q876 and Q1530.99. Both he and his family are almost fully employed. In the second and/or fourth quarter, they may hire a few labor hours, and in first and third quarters, they may sell a little labor, but neither the labor hired nor sold has a very large effect on total income. The only constraint facing the farmer in Set 12 is land. If he had another hectare of potato land, he could increase his income by about Q725. If he had another hectare of valley land, or if he could use capital intensive technologies on hilly lands and achieve yields comparable to his yields on valley lands, he could increase income by about Q150. More land would, however, mean the need for more hired labor or a move to mechanized production methods. A great many highland farmers would welcome the opportunity to become large enough to need hired labor or mechanization, but probably there are at least as many (or perhaps a larger number) who would be happy to have three hectares of land and grow approximately one hectare of potatoes, one hectare of wheat and one hectare of milpa as does the farmer in Set 12.

Resource Set 13--Solutions 46, 47, 48

Resource Set 13 adds a high level of vegetable knowledge to the farmer's resources in Set 12. This allows the farmer to grow one cuerda of green onions in each of the three optimal solutions and increases his average total income by about Q55 over average total income in Set 12. This increase is composed of an average increase of Q65.71 in cropping income and an average decrease of Q10.73 in labor sales income.

The solutions in Set 13 are quite similar to the corresponding solutions in Set 9 of Category 3. The only difference between Sets 9 and 13 is that the farmer in Set 13 uses an average of 170 hours (about 21 days) of hired labor in these three solutions. This extra labor is used to increase milpa production on hilly lands. Usage of hired labor does not, however, have much of an impact on average total income. Average total income in Set 13 increases by only Q5.43 over average total income in Set 9 in which no labor was hired. The increase of Q5.43 can be attributed to an increase in average crop income of Q36.05 and a decline in average labor sale income of Q30.62. The crops produced are very similar to those produced in Sets 9 and 12 (although no onions are produced in Set 12). Set 13 combines one cuerda of onions and one hectare of potatoes with either wheat and milpa production or corn and milpa production in all three solutions. Figures 5.11, 5.12 and 5.13 point out the similarities which exist between Sets 12 and 13 and also demonstrate that Set 13 differs from Set 12 in much the same way that Set 9 differed from Set 8 in Category 3.

The only constraint in Set 13 is land. The shadow prices on both hilly and valley land are positive, reflecting the fact that the farmer uses his entire three hectares of land for crop production. As is the case with almost all the other sets considered, the shadow price on valley land increases as the level of crop knowledge rises. The shadow price on hilly land follows the same pattern observed in Set 12 and remains relatively constant at about Q13.

<u>Resource Set 15--Solutions 52, 53, 54</u>

In Set 15, the farmer is given three hectares of potato land, a high level of vegetable knowledge, availability of ten hired laborers, credit, everything. Every variable is at the highest level which will be considered in the analysis. The farmer's response to this relative plethora of resources is to farm the entire three hectares and raise his average total income to Q2237.89. This is Q790.86 more than the average total income earned in Set 13 where the farmer had only one hectare of potato land and a high level of vegetable knowledge. Crop income is about 93% of total income in Set 15 and averages Q2073.23 for the three solutions. Local labor sales average Q71.46, and migratory labor sales remain constant at Q93.20 in all three solutions.

The severe shortage of labor experienced by the farmer in Set 10 of Category 3 who was also given three hectares of potato land has completely disappeared. The farmer in Set 15 hires an average of about 170 days' labor in first and second quarters. This is equivalent to hiring just over two men full-time in each of these two quarters. This amount of hired labor is well within the ten men allowed. Labor is definitely not a constraint in these solutions.

The two resources which are constraints are land and capital. In Solution 52, hilly land is the binding constraint. This is because the only potato activity the farmer is aware of with a crop knowledge level of TL1 requires slightly more hilly land than valley land. Since the farmer has plenty of labor, capital and valley land, the shadow price for hilly land must absorb the entire burden as the resource which prohibits the farmer from growing more potatoes. The shadow price on hilly land is consequently quite high, Q836.75, in Solution 52. The crops produced in this solution are 2.63 hectares of potatoes, 0.32 hectares of wheat and one cuerda of onions. In Solution 53, the farmer's crop knowledge level is increased to TL2. With a crop knowledge level of TL2, the farmer knows of a more productive and profitable potato activity which requires slightly more capital than the average size loan in 1972 and slightly more valley land than hilly land. Both of these factors impede the farmer from growing three hectares of potatoes, and so both working capital and valley land are constraints in Solution 52. Of the two, the shortage of capital is the more serious; the shadow price on capital is Q1.20. The shadow price on valley land is approximately Q175. Due to these shortages of working capital and valley land, the farmer cannot produce three hectares of potatoes, but he does manage to produce 2.18 hectares of potatoes, 0.24 hectares of corn alone, 0.54 hectares of milpa, and one cuerda of green onions. In Solution 54 with a crop knowledge level of TL3, the farmer learns of an even more advanced method of potato production which requires all valley land. This means that valley land is now a more limiting constraint than capital. The shadow price on valley land correspondingly increases to Q514.66 while the shadow price on savings declines moderately to Q0.91. The farmer produces 0.63 hectares of potatoes by this most advanced method (PV4), 1.45 hectares of potatoes by the next most advanced method (PHV3), 0.86 hectares of milpa and one cuerda of green onions. Production of these crops gives him a crop income of Q2312.77. When this is combined with his labor sales income, he earns a total income of Q2459.32. This is about five times the income earned by the farmer in Solution 1 of Category 1. Consequently, it appears that the resource levels considered here have the potential to increase income by about a multiple of 5 with respect to the levels of income considered in Category 1. Further increases would, of course, be possible on a larger farm.

Conclusions for the non-potato farmer in Category 4

Allowing the non-potato farmer to hire labor does not appreciably change the situation he faced in Category 3. Land upon which capital intensive technologies can be used to achieve high yields is the primary constraint in Category 4 just as it was in Category 3. Giving the farmer a chance to hire labor allows him to make somewhat better use of his other resources, but it does not allow him to appreciably increase total income. The increases in the value of cropping income are largely offset by decreases in labor sales income. If the farmer did not have the option of selling all his labor locally and was unemployed during parts of the year, the effect of hiring local labor to assist at peak periods would be greater. In this case, hiring local labor would result in an average increase in total income of about Q40 per year.

The only difference between Category 3 and Category 4 solutions is that the additional hired labor in Category 4 allows the farmer to increase crop income by about Q40 and decrease labor sales income by about Q35. The farmer makes some minor adjustments in the crops he produces and is able to increase production of milpa on hilly lands. This results in slightly more land being used in Category 4, but the net result of all changes is to increase average total income by only Q5.41.

Savings become a constraint in Solution 42 where the farmer is given a crop knowledge level of TL2. In this solution, the farmer grows 1.5 hectares of corn alone on valley land using a very capital intensive production activity (CV4) which in 1973 was used only on demonstration plots. This activity requires considerably more capital per hectare than did a typical corn alone or milpa activity in 1973. The farmer has enough capital to produce 1.5 hectares of corn alone, but as a result of using so much capital on his valley lands, he does not have enough capital to produce milpa on hilly land. He consequently has to leave almost one-half hectare of hilly land lying fallow. This causes the shadow price on hilly land to fall to zero and the shadow price on capital to increase from Q0.05 to Q0.30. Again, one is reminded that as farmers learn of new technologies, there will be a need for lending authorities to increase average size loans to ensure that farmers have sufficient capital to allow them to adopt new technologies.

The average amount of labor hired in Category 4 suggests that hiring labor will not result in any major changes. Labor is hired only in fourth quarter, and an average of only 26 days of fourth quarter labor is hired for these three solutions. The shadow price on valley land of Q136.06 (Solution 42) where the farmer has a crop knowledge level of TL2 indicates that as in Category 3, valley land is the primary constraint. As was mentioned in the section dealing with conclusions for the non-potato farmer in Category 3, the farmer needs more land upon which he can achieve higher yields. If hilly land could be used with capital intensive technologies, then it might be possible to earn a total income of Q850 from farming three hectares of hilly and valley land. If not, it appears that total income will not be increased much above Q700 for farmers with 1.5 hectares of hilly land and 1.5 hectares of valley land.

Conclusions for the potato farmer in Category 4

The potato farmer in Category 4 with one hectare of potato land receives only a marginal amount of help by being allowed to hire labor. As was the case with the non-potato farmer in Category 4, availability of hired labor allows the farmer to make better use of other resources but does not substantially increase his level of total income. Crop income is increased, labor sales income is decreased, and total income remains about as it was.

The amounts of labor hired by potato farmers with one hectare of potato land for the six solutions in Sets 12 and 13 average about fourteen days per solution. More labor is hired in Set 13 than in Set 12, and more labor is hired with higher levels of crop knowledge than with lower levels of crop knowledge, but the differences are not very important, because the amounts hired in all solutions are quite small. For example, the amount of labor hired ranges from zero hours with a crop knowledge level of TL0 in Set 12 to 274 hours (about 35 days) in Set 13 with a crop knowledge level of TL2. The reason for this low use of hired labor is that potato production requires the most labor in second quarter while wheat, corn and milpa require the most labor in fourth quarter. The difference in periods of peak labor requirements results in potato production being complementary with production of other crops. A combination of potato production and milpa, wheat, or corn alone production allows the farmer to have a more balanced quarterly demand for labor and, therefore, not as much extra labor is required at peak periods. Availability of hired labor makes little difference to potato farmers with one hectare of potato land. The results in Sets 12 and 13 of Category 4 are consequently very similar to the results in Sets 8 and 9 of Category 3 in which the farmer was not allowed to hire local labor to assist with crop production activities.

The potato farmer with three hectares of potato land is in an entirely different position. In Set 10 of Category 3, the potato farmer experienced a severe shortage of second quarter labor. Allowing the farmer in Set 15 to hire labor releases this labor constraint. The potato farmer in Set 15 hired an average of 187 hours (23 days) of hired labor in 1st quarter and 713 hours (89 days) of hired labor in second quarter. This hired labor allows the farmer to expand his average amount of land in potato production from about 1.8 hectares in Set 10 to about 2.2 hectares in Set 15. It also allows the farmer in Set 15 to produce onions, wheat, corn alone, and milpa as well as potatoes. The expansion in land devoted to potato production and the increased income from sales of other crops allow the farmer in Set 15 to earn an average income of Q2237.89, an increase of about Q360 over the average total income earned in Set 10. Thus, the availability of hired labor for the farmer with three hectares of potato land proves to be very beneficial.

Another result of increasing the amount of labor available in Set 15 is to make land and working capital the primary constraints. Working capital becomes a constraint as the farmer acquires additional crop knowledge which makes him aware of newer, more capital intensive technologies. Land is a constraint because the three levels of crop knowledge do not have potato activities which require exactly one-half hilly and one-half valley land. The type of land which is in shortest supply is, therefore, dependent upon the farmer's level of crop knowledge.

CHAPTER VI. A DISCUSSION AND COMPARISON OF THE RESULTS

This study has attempted to reproduce the economic life of a minifundista, or small farmer, living in the western highlands of Guatemala. It is focused primarily on production of traditional crops such as corn alone, milpa, wheat and potatoes but also includes five vegetable activities among the farmer's production alternatives. The study begins with a small farmer who has only one hectare of land, Q50 savings, no access to a source of credit, no availability of hired labor, no potato land, a low level of vegetable knowledge, and a low level of crop knowledge. The study then estimates how the farmer's income and employment would be affected by a Government program(s) designed to increase the farmer's supply of one or more of the above mentioned resources.

Policymakers in Guatemala have identified a shortage of working capital and insufficient knowledge of new technologies as two of the most restrictive constraints facing small farmers. The Ministry of Agriculture, working through its General Agricultural Services Administration (DIGESA) and the National Agricultural Development Bank (BANDESA), has initiated a program called the Basic Grains Program. One of the primary goals of the Basic Grains Program is to provide small farmers with agricultural credit and technical assistance which will enable them to adopt newer high yield agricultural technologies. The present analysis has examined the impact of this goal on small farmers by estimating the farm level effects of a credit provision and crop knowledge increasing program.

Two farm sizes are investigated in this study, one and three hectares. At present there is no Government program which has the primary task of investigating the importance of farm size as a constraint upon the farmer's ability to increase his income, although this is recognized as a very serious constraint. The question of the optimal or the necessary farm size to enable small farmers to earn a given level of family income is an important question for Guatemala. It is important from both political and agricultural policy viewpoints, because most of the farmers in Guatemala are minifundistas and do live on very small farms.

Tables 6.1 and 6.2 provide us with information on the numbers of farmers who lived on different sized farms in 1964. Table 6.1 shows us that in 1964, 45% of the farmers in the nine highland departments which Merrill (1974) analyzed lived on farms that were smaller than 1.4 hectares; 75% of these farmers lived on farms that were smaller than 3.5 hectares. Table 6.2 points out that in the departments of Sololá, Quezaltenango, and Totonicapan, the percentage of very small farms is significantly higher than in the region as a whole. In these departments, more than 60% of all farmers had farms that were smaller than 1.4 hectares. Since the Basic Grains Program has been conceived as a means of helping the small farmer, it was decided that this analysis should limit itself to farms of one and three hectares. Table 6.2 points out that about 22% of all farmers in the nine highland departments have less than 0.7

Table 6.1. Land distribution, 1964[a]

Farm size (in hectares)	Farms		Area	
	No.	%	1000 ha	%
Total nine highland departments				
Less than 1.4	114,053	45	72.2	5
1.4 to 3.5	78,069	30	168.4	11
3.5 to 7.0	35,340	14	166.0	10
7.0 to 45	25,131	10	351.0	22
Over 45	3,243	1	816.4	52
Total	255,836	100	1,574.0	100
Republic				
Less than 1.4	183,741	44	128.1	4
1.4 to 3.5	129,116	31	270.7	8
3.5 to 7.0	52,023	12	242.8	7
7.0 to 45	43,656	10	650.1	19
Over 45	8,808	3	2,157.0	62
Total	417,388	100	3,448.7	100

[a]Merrill, 1974, p. 34.

Table 6.2. Percent of farms with less than 1.4 hectares, 1964[a]

Department	Farms with less than 0.7 ha		Farms with 0.7 to 1.4 ha		Farms with less than 1.4 ha	
	No.	%	No.	%	No.	%
Chimaltenango	3,548	16.7	5,755	27.1	9,303	43.8
Sololá	5,065	32.3	4,393	28.0	9,458	60.3
Totonicapan	11,037	48.7	4,976	22.0	16,013	70.7
Quezaltenango	11,100	42.7	6,001	23.1	17,101	65.8
San Marcos	9,900	24.4	8.705	21.5	18,605	45.9
Huehuetenango	6,169	14.8	9,091	21.8	15,260	36.6
Quiché	4,809	12.9	6,903	18.5	11,712	31.4
Alta Verapaz	3,332	9.0	9,277	25.1	12,609	34.1
Baja Verapaz	1,157	8.4	2,835	20.5	3,992	28.9
Total nine highland departments	56,117	21.9	57,936	22.6	114,053	44.6

[a]1964 Agricultural Census, Volume II.

hectares of land, and another 23% have farms that are larger than 0.7 hectares but smaller than 1.4 hectares. The one hectare farm has been chosen as being a representative size for these two groups. Another 30% of farmers have farms larger than 1.4 hectares and smaller than 3.5 hectares. The three hectare farm has been chosen as a representative farm size for this group. Independent comparisons of results from the agricultural credit and technical assistance components of the Basic Grains Program will be presented for these two farm sizes.

In Chapter V, we saw that farmers who grew potatoes earned substantially larger incomes than farmers who did not. The ability to grow high yield potatoes was represented in the model as being attributable to two factors. The farmer needed knowledge of new high yield potato technologies, and he needed land that was climatically and agronomically suitable for potato production. The conclusions of the four resource sets considered in Chapter V were, consequently, divided into results for farmers who had potato land and results for farmers who did not. The same pattern will be followed here. The overall evaluation of the potential results of the Basic Grains Program will be subdivided into results for farmers who grow potatoes and farmers who do not.

The decision to separately consider the effects of the Basic Grains Program upon farmers with different farm sizes and upon farmers who are (or are not) able to grow potatoes means that the discussion and comparison of results from Chapter V will need to be divided into four subsets. These four subsets will be: (1) the non-potato farmer with one hectare of crop land; (2) the non-potato farmer with three hectares of crop land; (3) the potato farmer with one hectare of crop land; and (4) the potato farmer with three hectares of crop land. These four subsets represent the heart of the linear programming model's contribution to the present analysis. As such, they constitute the basis upon which many of the following conclusions must rest and are a central element in the analysis. There is, however, one other element, which is as important as the conclusions derived from the linear programming solutions, which has not been presented thus far. This other element concerns the reliability of the model and, consequently, the reliability of the conclusions. It is a discussion of the model's ability to reproduce the present position of the small farmer. If the model is to successfully estimate potential effects of Government programs, its estimates should be firmly grounded in reality. Let us now consider how realistic the model's estimates are.

The Ability of the Model to Reproduce the Position of the Small Farmer

It is difficult to judge precisely how well the model reproduces the position of the small farmer, because there is not much information which can be relied upon to tell us what the small farmer's position is. There is not even a clear definition of who is a small farmer. Does the small farmer have one hectare of land, three hectares of land, or five hectares of land? Is this valley land, mountain land, or irrigated land? Several studies have investigated the question of small farm and agricultural labor income levels, but their results are not always comparable. There are several reasons for this. First, the studies do not break out information on the effects of farm size, irrigation water, or soil quality in determining family income. All of these factors are, of course, very important. In four of the studies which will be referred to, there is information on average income and average farm size, but averages sometimes conceal as much as they reveal. Second, there are differences in the way in which income is measured. For example, Dr. Manger-Cats (1966) includes values for firewood gathered, handicrafts produced, consumption and sale of livestock products, and local and migratory labor sales in addition to values for consumption and sale of crops in constructing estimates of family income. Other studies have not included estimates for all these sources of income, and it is not possible to tell which of the above income earning activities have been considered in computing the different income estimates. Third, there are probably differences between the sample populations from which these income estimates are derived. For example, in some highland communities, handicraft production and other non-cropping sources of income such as migratory labor sales are more important than in other communities. Average family incomes may, therefore, vary between communities because in one community migratory labor sales may be a traditional activity while in other communities tradition may dictate that most families do not engage in migratory labor sales. There are undoubtedly other reasonable explanations for the differences in income estimates reported in Table 6.3. The explanations presented here are given simply to suggest the difficulty which arises when one tries to compare these estimates too closely.

Table 6.3 also presents income estimates which were generated by the linear programming model under different assumptions concerning the amounts of land and other resources which the farmer may be assumed to have available. Estimates 6 and 10 were made from solutions in which the farmer and his family were not allowed to sell as much of their labor locally as they pleased. These two estimates were made by averaging income estimates for Solutions 55, 56, 57, 58, and 59. In these solutions, the farmer and his family were allowed to sell only ¼ of their total labor supply locally in first, second, and third quarters; in fourth quarter they were allowed to sell ½ of their total labor supply locally. More local labor sales were permitted in fourth quarter, because there is generally a larger demand for hired labor during the corn and wheat harvests. This restriction results in a reduction of total income, an increase in crop income, and a reduction in other income for Estimates 6 and 10 when compared with Estimates 7 and 11 which were also generated by the model. In Estimates 7 and 11, local labor sales were not restricted. The family was allowed to sell all its labor locally if this would increase its income. Hence, in Estimates 7 and 11,

Table 6.3. Peasant family incomes

No.	Total income (Q)	Agricultural income (Q)	Other income (Q)	Average size (ha)	Year	Source
1	396.00	69.00	327.00	0.7	1965	Manger-Cats[a]
2	520.00	324.00	196.00	0.8	1965	Manger-Cats[b]
3	206.77	Unknown	Unknown	0-0.7	1966	Orellana[c]
4	268.71	169.90	98.81	Unknown	1967	Hill and Gollas[d]
5	258.00	213.00	45.00	0.87	1970	Pérez[e]
6[h]	325.97	127.31	198.66	1.0	1973	Appendix A, solutions 55, 56, 57
7	459.21	98.14	361.07	1.0	1973	Appendix A, solutions 1, 2, 19, 20
8	286.26	Unknown	Unknown	0.7-7.0	1966	Orrellana[c]

9	542.19	321.02[f]	221.17[f]	3.3	1966	Gremial[g]
10[h]	478.65	325.43	153.22	3.0	1973	Appendix A, solutions 58, 59, 60, 61
11	524.62	276.91	247.71	3.0	1973	Appendix A, solutions 40, 41, 62 63

[a]Manger-Cats, 1966, pp. 118-119. This is an estimate of average gross income for 35 agricultural laborers that worked on the southern coastal plain. Of this Q396, Q245 is from wages, Q82 is from fringe benefits, and Q69 is from value of crops produced on the 0.7 hectare plot which the owner of the farm let them use.

[b]Manger-Cats, 1966, pp. 139-140. This is an extimate of incomes earned by minifundistas in the western highlands. The agricultural income includes Q91 from sale of crops, Q45 from sale of livestock products, and Q188 from value of crops and livestock products consumed on the farm.

[c]Orellana, 1966, p. 119.

[d]Hill, G. W. and M. Gollas, 1968.

[e]Pérez, 1971, p. 157.

[f]The Q321.02 is income from only wheat production. The Q221.17 is income from sale of other crops plus all other income.

[g]Gremial, 1967, Table 76.

[h]Local labor sales are limited in this solution.

the model implicitly assumes that the family will be fully employed.

The levels of crop knowledge specified in the solutions used to calculate income Estimates 6, 7, 10, and 11 were TLO and TL1. These are the two lowest levels of crop knowledge considered in this study. Level TLO is a traditional level of crop knowledge used by poorer farmers. Level TL1 is a level which the better farmers were using in 1973. The implicit assumption used to estimate income levels in Estimates 6, 7, 10, and 11 is that 50% of the farmers in a typical village have crop knowledge level TLO and 50% have level TL1. Increasing the farmer's level of crop knowledge in the model would have the effect of increasing the level of total income, increasing the level of agricultural income, and decreasing the level of other income in Table 6.3. Estimates 6, 7, 10, and 11 also implicitly assume that 50% of the farmers in a village have only Q50 per hectare of land available to finance crop production and 50% of the farmers are able to obtain credit (Government crop specific credit is used as the source of credit here, but the credit might have come from any source).

The levels of total income estimated by the model in Table 6.3 are not in complete agreement with any of the other estimates. Instead, they appear to be intermediate or almost average estimates. For instance, if we simply average the amounts of total income for Estimates 1, 2, 3, 4, and 5, we get Q329.90 which is very close to Estimate 6 (produced by Solutions 55, 56, and 57) in which the family's sale of local labor was limited to ¼ of its total supply in the first three quarters and ½ of its total supply in fourth quarter. This suggests that some of the families giving information on income levels in Estimates 1, 2, 3, 4, and 5 were not able to devote all their labor hours to activities which earned at least 7.5¢ per hour and that they were unemployed or underemployed during certain times of the year. This is admittedly a rather crude way of making a comparison, because as was pointed out earlier, these estimates are probably not very comparable.

One might, on the other hand, believe that the level of income in Estimate 2 (Q520) made by Dr. Manger-Cats is the most realistic estimate. As was mentioned earlier, Dr. Manger-Cats included a large number of income earning activities in compiling his income estimates. Dr. Manger-Cats writes:

> The minifundistas in the highlands generally work most of the time (233 days) outside the farm in different activities such as agricultural workers, as help for the neighbors, as craftsmen or in trade and business. The general pattern is that nearly all minifundistas work in a combination of many different occupations. It was calculated in this study that on the average, only 13% of the time they were idle. The wide variety of jobs and activities besides the work on their own fields means that they are less unemployed or underemployed than would seem to be the case at first sight. This does not contradict earlier remarks about a lack of job opportunities, because, though a host of little jobs are available which keep them busy, the marginal return is very low (Manger-Cats, 1966, p. 136).

If Dr. Manger-Cats' findings regarding employment can be generalized to other parts of the highlands, then perhaps Estimate 7, which was produced by the model under the assumption that the farmer and his family are able to find unlimited local employment at 7.5¢ per hour, is quite a good estimate for total income. It is not quite as high as found by Dr. Manger-Cats, but it is a good deal closer than any other estimate.

Estimates 10 and 11 were generated by the model for the three hectare farm. Estimate 11 (Q524.62) appears to agree quite well with the only other estimate (number 9) (Q542.19) which was made for a farm of about the same size (3.3 hectares). The problem of off-farm employment is not as serious in Estimate 11 as it was in Estimate 7, because the farmer and his family are able to be more nearly fully employed on the three hectare farm than on the one hectare farm. Estimate 8 (Q286.26) does not give an average size and so it is difficult to judge to what extent it can be compared with the three hectare farms of Estimates 9, 10, and 11.

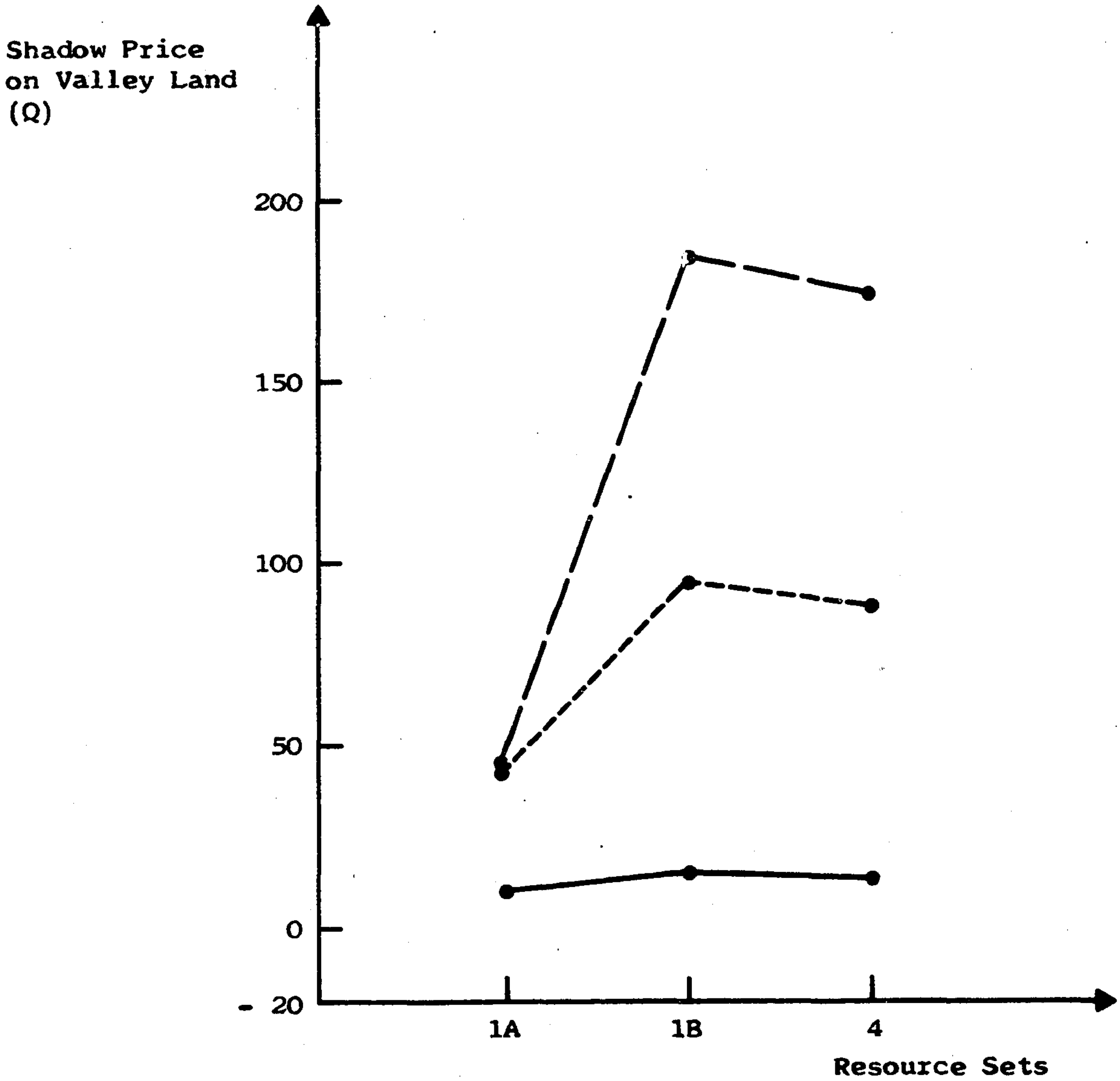
The data presented in Table 6.3 illustrate that income estimates do differ, sometimes quite widely. As a result, it is quite difficult to judge precisely how well the model reproduces the actual situation. Table 6.3 does, however, show us that the estimates the model generates are definitely in the same ball park as the estimates made by different studies conducted in the field. It, therefore, seems reasonable to conclude that the model does do a satisfactory job of reproducing the present situation.

The Non-potato Farmer With One Hectare of Land

As was pointed out in Table 6.1, 45% of all farmers in the nine highland departments (and 44% of all farmers in Guatemala) have farms that are smaller than 1.4 hectares. Only about 2% of these farmers grow potatoes. Therefore, when one discusses the situation experienced by the non-potato farmer with one hectare of crop land, one discusses a position which is shared by about 42% of all Guatemalan farmers.

Categories 1 and 2 of Chapter V discussed the situation faced by the farmer with one hectare of land. Within these two categories, Resource Sets 1A, 1B and 4 were devoted to analyzing the position of the non-potato farmer under different assumptions concerning availability of working capital to finance crop production. In Set 1A, the farmer was assumed to have Q50 personal savings which could be used to finance production, but he was unable to acquire credit. In Set 1B, he was assumed to have Q150 savings and was still unable to borrow additional capital. In Set 4, the farmer had Q50 savings and was assumed to be able to borrow additional money by enrolling in the Government's crop specific credit program.

One of the most significant findings in Categories 1 and 2 was that the estimates of crops produced, of income earned, and so on for Set 1B were nearly identical to the corresponding estimates made by Set 4. This occurred because in Set 1A, the single most important constraint had been the farmer's limited amount of working capital. In Set 1B, this savings constraint was eased by providing the farmer with additional savings, while in Set 4, it was eased by providing the farmer with credit. In both Sets 1B and 4, providing the farmer with an adequate amount of working capital to finance crop production activities had the effect of causing valley land to replace savings as the most binding constraint. Figures 6.1 and 6.2 present information on shadow prices for valley and hilly land in Resource Sets 1A, 1B and 4. These figures suggest three of the most important conclusions which can be drawn from the solutions for the non-potato farmer with one hectare of crop land. First, they show us that providing the farmer with an adequate amount of savings (Set 1B) or a source of credit (Set 4) will allow the farmer to increase the amount of income he can earn from an additional hectare of either hilly or valley land. The increased value of shadow prices on land in Sets 1B and 4 suggests that savings had been the most severe constraint in Set 1A, but that with an adequate amount of savings or credit, land becomes the most severe constraint. Second, the fact that shadow prices on hilly and valley land are positive when the farmer has a crop knowledge level of TLO indicates that crop activities can successfully compete with labor sales activities for the farmer's time and that traditional crop production is not a form of disguised unemployment. Third, these figures illustrate that the farmer can make much better use of additional savings or credit when he has a higher level of crop knowledge. With a crop knowledge level of TLO, giving the farmer additional working capital increases the shadow

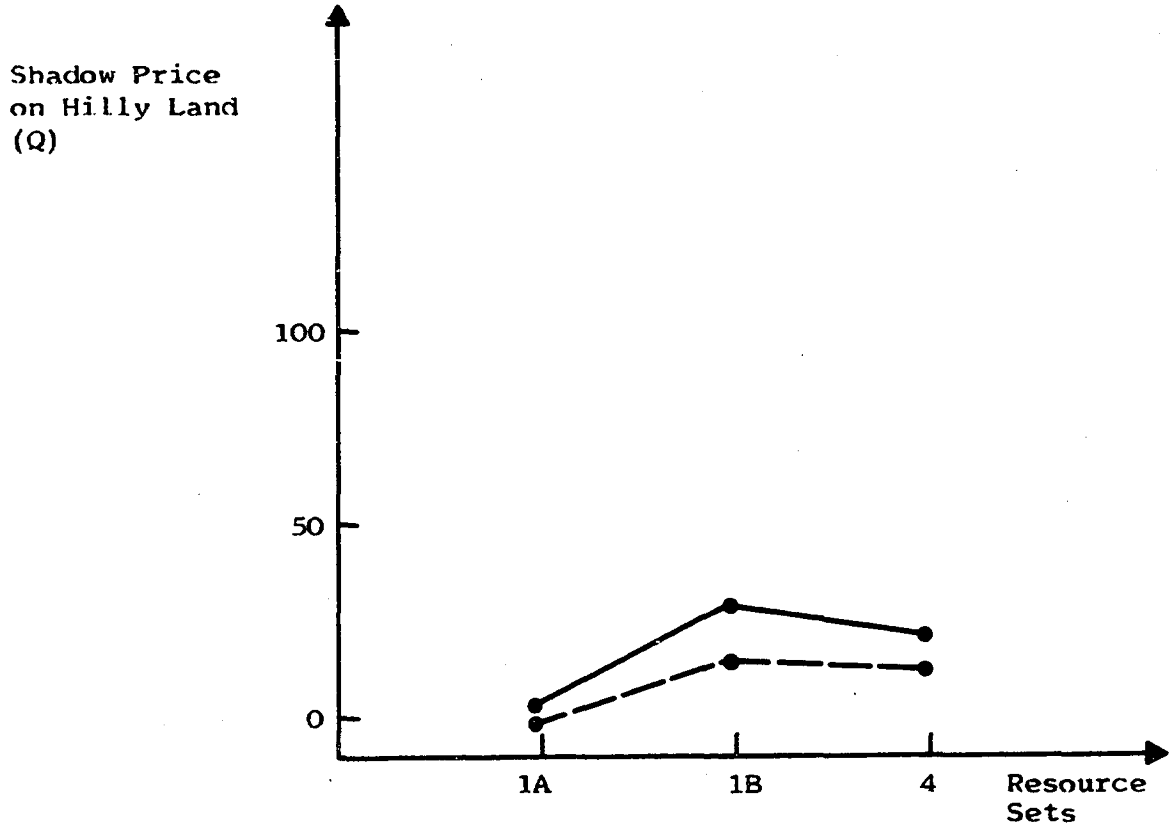


Semi-fixed Resources

Savings	50	150	50
Credit	None	None	Gov't
Ha. of crop land	1	1	1
Local laborers available	10	10	10

——— Crop knowledge level 0
- - - - Crop knowledge level 1
— — — Crop knowledge level 2

Figure 6.1. Shadow prices on valley land for the one hectare non-potato farmer



Semi-fixed Resources

	1A	1B	4
Savings	40	150	50
Credit	None	None	Gov't
Ha. of crop land	1	1	1
Local laborers available	10	10	10

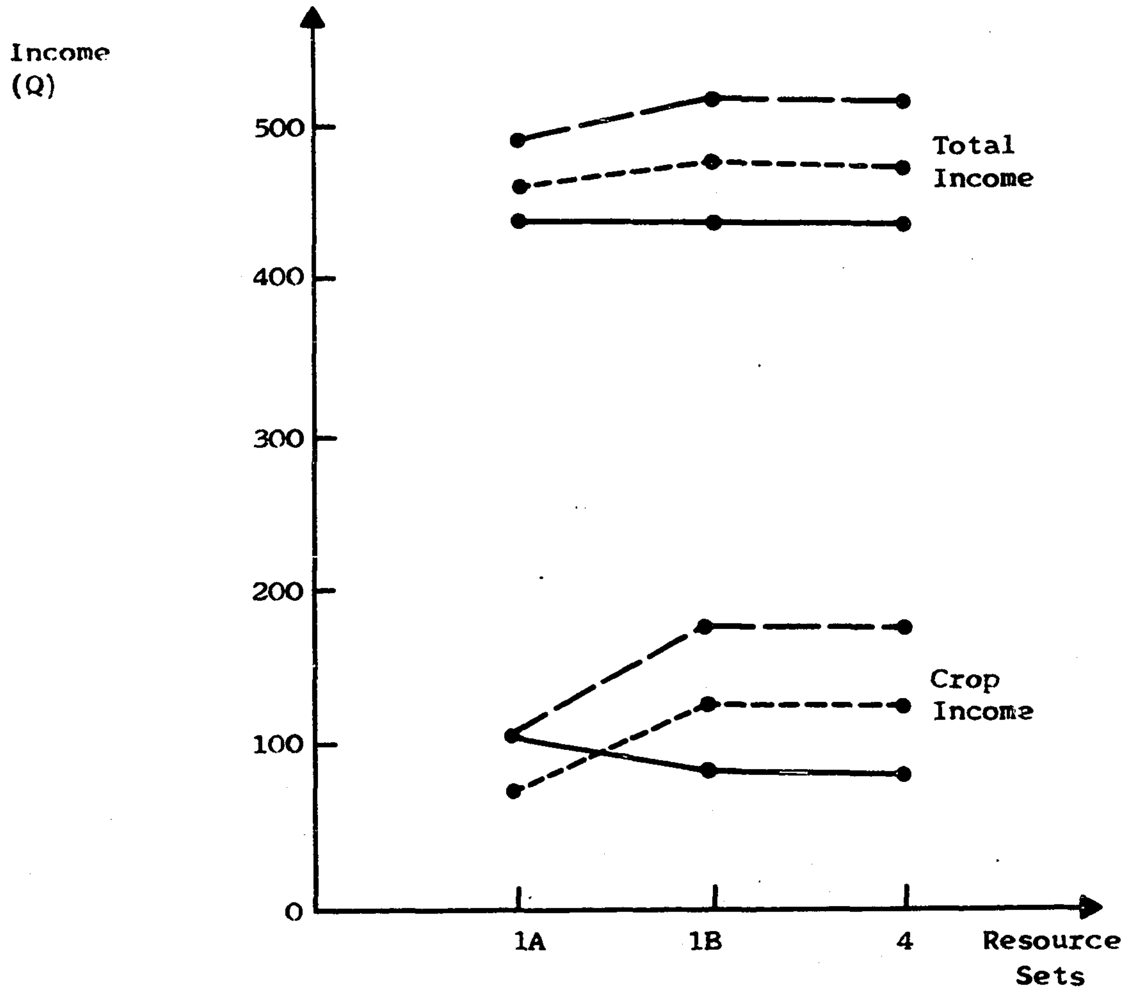
——— Crop knowledge level 0

— — Crop knowledge levels 1 and 2

Figure 6.2. Shadow prices on hilly land for the one hectare non-potato farmer

price on hilly land by only about Q25 (the shadow price on valley land rises by only about Q4), but when the level of crop knowledge is increased to TL2, additional working capital causes the shadow price on valley land to increase by about Q130. The comparatively higher shadow prices on valley land for solutions in which the farmer has a crop knowledge level of TL1 and TL2 point out that the Basic Grains Program holds considerable potential for helping farmers with farms of two, three, or more hectares. The program is not quite as effective at helping the farmer with one hectare of land because his farm is too small to fully employ the farmer and his family.

Figure 6.3 summarizes information on the levels of total and crop income earned by non-potato farmers in Categories 1 and 2. Total income increases by about Q80 when the farmer is provided with credit and technical assistance, while crop income increases by about Q90. An increase of Q80 for a farmer with an annual income of Q450 represents an 18% increase. This is an important increase, but income still falls far short of the Q1000 target level mentioned in Chapters I and III. Figure 6.3 also points out that income from sale of crops is not and will not be the family's major source of income. Crop income accounts for only about 35% of total income on the one hectare non-potato farm. The one hectare farm is too small to provide full employment for a family with a total labor supply equivalent to 2.1 farm laborers. Consequently, the one hectare corn, milpa, and wheat farmer is and will be essentially a marginal farmer, because he must supplement farm employment with off-farm work if



Semi-fixed Resources

	1A	1B	4
Savings	50	150	50
Credit	None	None	Gov't
Ha. of land	1	1	1
Local laborers available	10	10	10

Crop knowledge level 0
Crop knowledge level 1
Crop knowledge level 2

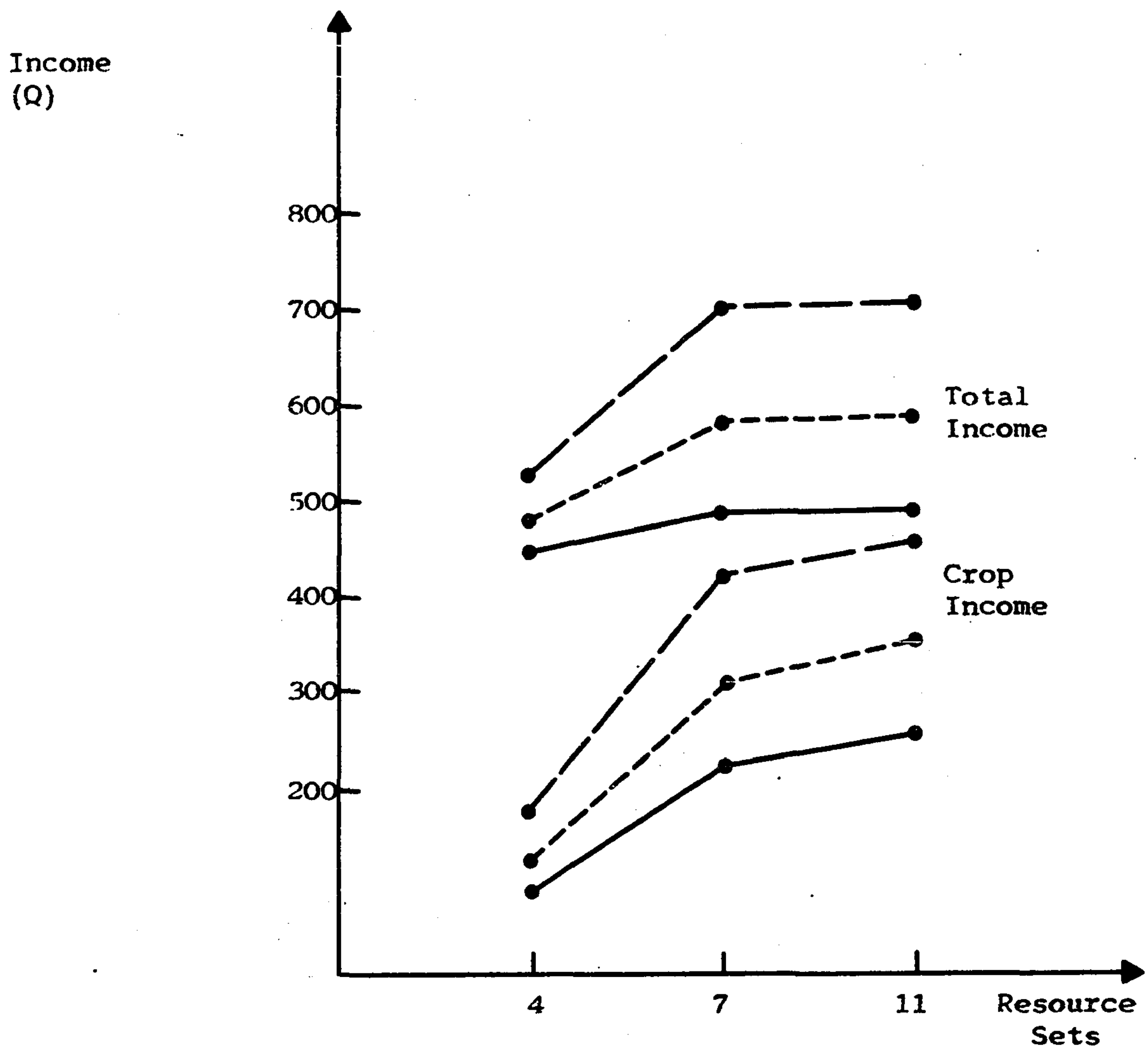
Figure 6.3. Levels of total and crop income in Resource Sets 1A, 1B, and 4

he and his family are to be fully employed.

One qualification must be mentioned here concerning the model's income estimates. The levels of total income presented in Figure 6.3 implicitly assume that the farmer and his family are fully employed, because the model allows them to sell up to 100% of their labor locally. If this assumption is unwarranted, and if farmers are seasonally underemployed or unemployed, then the levels of income earned from labor sales activities should be reduced, which would cause the levels of total income in Figure 6.3 to be reduced by about the same amount as the reduction in labor sales income or perhaps by a little less.

The Non-potato Farmer With Three Hectares of Land

Categories 3 and 4 increase the farmer's amount of crop land to three hectares. In Category 3, the farmer was given three hectares of land, but was not allowed to hire local labor to assist with crop production activities. In Category 4, the farmer was permitted to hire local labor. The resource sets which presented solutions for the non-potato farmer in Categories 3 and 4 were Sets 7 and 11. Figures 6.4 and 6.5 show how the farmer's level of total and crop income and the shadow price on valley land are affected by these changes in the resource sets. The estimated values in Figures 6.4 and 6.5 from Sets 7 and 11 are presented with the estimated values from Set 4 in which the farmer had only one hectare of crop land. This is done to facilitate comparison between these

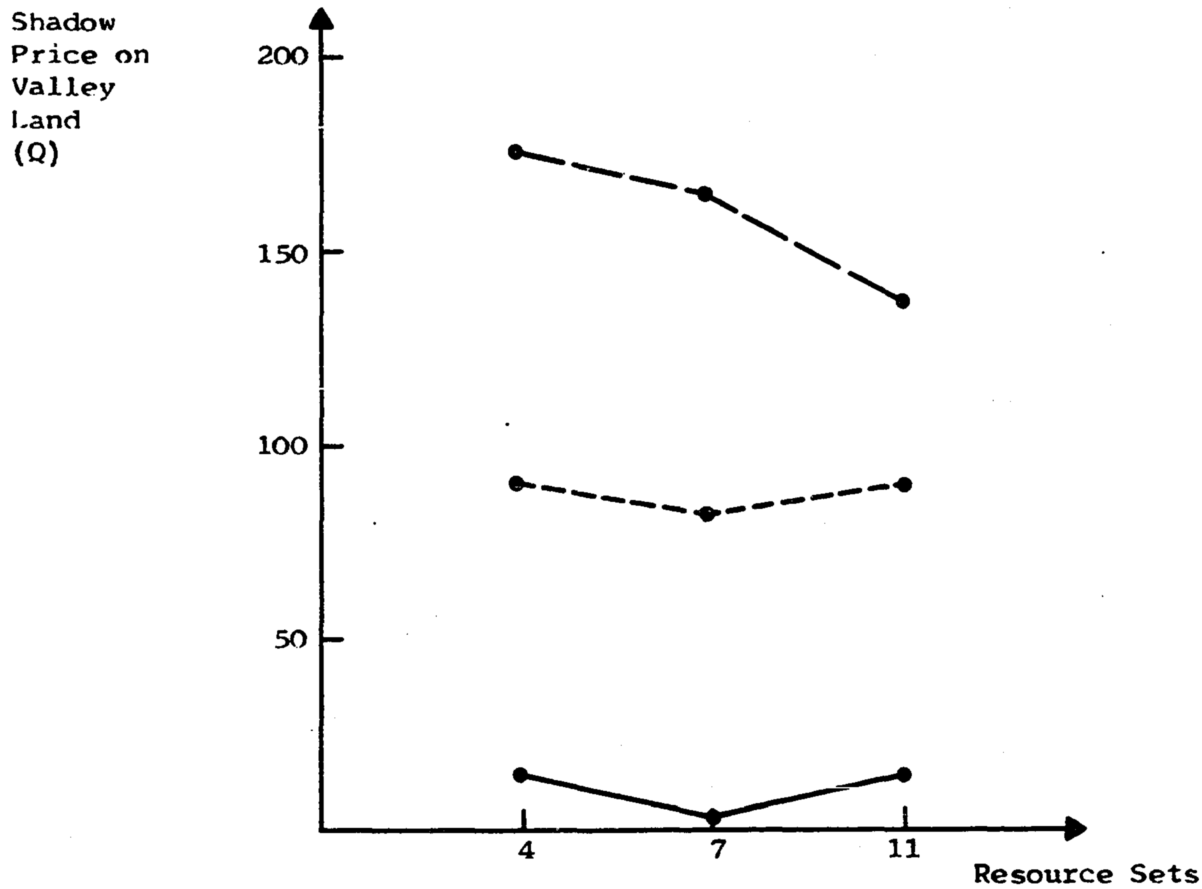


Semi-fixed Resources

Savings	50	50	50
Credit	Gov't	Gov't	Gov't
Ha. of land	1	3	3
Local laborers available	10	0	10

Crop knowledge level 0
Crop knowledge level 1
Crop knowledge level 2

Figure 6.4. Levels of total and crop income in Resource Sets 4, 7, and 11



Semi-fixed Resources

Savings	50	50	50
Credit	Gov't	Gov't	Gov't
Ha. of crop land	1	3	3
Local laborers available	10	0	10

Crop knowledge level 0
Crop knowledge level 1
Crop knowledge level 2

Figure 6.5. Shadow prices on valley land in Resource Sets 4, 7, and 11

results and the results presented earlier for Categories 1 and 2.

In Figure 6.4, the farmer has been given an additional hectare of hilly and an additional hectare of valley land. This allows the farmer with a crop knowledge level of TL2 to achieve an income level of approximately Q700. Only about Q450 of this Q700 would be earned by selling crops; the remainder would be derived from local and migratory labor sales activities.

The amount of hired labor available does not have much effect upon the level of total income the farmer earns in these solutions, although it does have a small effect on his level of crop income. The solutions for Sets 7 and 11 which were presented in Chapter V pointed out that the farmer with three hectares of crop land was only beginning to experience seasonal shortages of hired labor. These shortages were not particularly important, because the amounts of hired labor needed on a three hectare farm are quite small. The effect of allowing local labor to be hired on the three hectare farm (Set 11) was to increase the farmer's use of hilly land for milpa production, to increase crop income by about Q30 or Q40, and to decrease local labor sales income by about Q25 or Q30. Although restricting hiring of local labor did not have a very important effect on the results for the three hectare farm, the fact that there was some effect indicates that a three hectare farm is about as large as a family with a labor supply equivalent to 2.1 adult male workers can farm by itself. Farms of over three hectares will need to rely on a larger pool of family labor, on additional supplies of local hired labor, or on mechanized means of production in order to relieve the seasonal shortages of family labor observed here.

The level of income earned on the three hectare farm varies between Q480 and Q700, depending on the farmer's level of crop knowledge. The potential farm level effect of the technical assistance component of the Basic Grains Program could, therefore, be estimated as an increase in income of about Q220 (an increase of 46%). This increase will only be possible if the farmer has an adequate supply of working capital. The amounts of credit provided by the Government's crop specific credit program were adequate in all solutions but one. When the farmer was given a crop knowledge level of TL2 in Set 11, the farmer experienced a shortage of credit for corn and milpa production, because level TL2 includes a corn alone activity which requires more working capital per hectare than is currently made available. The shortage was not, however, too serious.

It does not appear that it will be possible for the non-potato farmer to earn an income of Q1000. Even assuming that yields on hilly lands could be increased to the same levels specified in the model for valley lands, the farmer would need four hectares of land to earn an income of Q1000. In Table 2.3, we saw that the average farm size in 1980 has been projected to be five hectares or 0.69 hectares per person in the rural population. The family of four hypothesized here would then have only 2.76 hectares of land by 1980. In Table 2.4, we saw that only about 24% of this 2.76 hectares would be good land, but even if it were all good land, it is unlikely that the family could earn an income of Q1000 from farming it. The results in Categories 3 and 4 suggest that a farm with 2.76 hectares of good valley land could earn an income of about Q900, but only 0.66 of the projected 2.76 hectares would be good valley land.

By the year 2000, average farm size is projected to decline to four hectares, and farm land per person is projected to decline to 0.42 hectares. If present trends continue, a family of four in the year 2000 would have a farm of only 1.68 hectares. The results in Categories 3 and 4 suggest that with 1.68 hectares of good valley land, the family could earn a total income of about Q700, but again one must realize that only 0.40 of the projected 1.68 hectares could probably be classified as good valley land assuming that good valley land were available on a typical farm in the highlands in the same proportions as it is estimated to exist in the highlands as a whole.

The lack of information on yield levels for newer capital intensive technologies on hilly poorer lands makes it very difficult to accurately estimate family income levels even when one assumes that the Basic Grains Program will be successful in providing small farmers with credit and knowledge of new technologies. For the moment, one can only observe that even if hilly lands are capable of producing yields equal to yields on valley land, it does not appear that farms will be large enough to allow a family of four in the years 1980 or 2000 to earn an income level of Q1000 per year.

While it does not appear as though a non-potato farm family of four persons with either one or three hectares of crop land will be able to earn an income of Q1000 per year by 1980, there does appear to be a slight possibility that a family of six could. As was mentioned above, the estimates presented in Category 4 suggest that the farm family would need at least four hectares of good valley land to earn this much income. In 1980, the amount of land per person in the rural population is projected to be 0.69 hectares. Six people times 0.69 ha/person equals 4.14 hectares. Thus, in terms of the projected amount of land available per person in 1980, a family of six would have the required amount of land. Of course, only 24% or 0.99 hectares of the 4.14 hectares could be classified as good land. If, however, the farmer was able to achieve yields from hilly poorer lands equivalent to the yields the model specifies for good valley land, then there is at least a possibility of reaching the target level of income. If the typical family of six would be composed of husband, wife, two children and two grandparents, then there is hope that Guatemala will be able to increase family incomes into and through the 1980's. If, however, the family of six would be composed of husband, wife and four children, then there is little hope of increasing family incomes to the target level of Q1000 by the year 2000. It is vitally important that population growth rates be brought under control, because projected man/land ratios for the rural population suggest that in the year 2000, family size would have to be increased to 9.52 persons for the family to have a farm of four hectares. Thus, although there does appear to be a slight hope of achieving the goal of increasing family income to Q1000 per year by 1980, it is clear that measures will need to be taken to move workers out of traditional agriculture and also to halt or slow the rapid growth in rural population. A family of six might get along comparatively well on a four hectare farm which provides Q1000 per year, but a family of nine would not do nearly as well.

Without information on the amounts by which yields can be increased through application of newer technologies on hilly land, it is difficult to predict whether the farm family will be able to reach the targeted income level of Q1000. It was pointed out that if technified yields on hilly lands were comparable to technified yields on valley lands, then a family with four hectares of land would probably be able to reach this target level for income. The question of yield response on hilly land may not, however, be the key issue. While it may be physically and technically possible for a family to earn Q1000 from four hectares of land, it may turn out to be politically impossible. One must not forget that a tremendous redistribution of land would have to take place before the typical farm size could be increased to four hectares. At present, 45% of the farms in the highlands have less than 1.4 hectares of land, and 75% of highland farms have less than 3.5 hectares. Land redistribution or reform is often a delicate question in developing countries. It is certainly a delicate issue in Guatemala, and it is not clear that land redistribution is even a possibility given existing political structures. Nevertheless, the results of the linear programming analysis suggest that there is no chance of farm family incomes reaching Q1000 on the one or three hectare farms. Farms would have to be at least four hectares before incomes could reach this level, and even then the farmer would have to have: (1) an adequate supply of working capital; (2) a crop knowledge level of TL2; and (3) four hectares of land which will produce yields comparable to the yields the model specifies for production activities which require a crop knowledge level of TL2.

It is not unreasonable to expect that the Basic Grains Program will be successful in providing farmers with technical assistance and credit. Consequently, it appears that one of the major effects of the Basic Grains Program will be to cause land to replace credit as the farmer's most restrictive constraint. In the process, the program should also increase family incomes by between 18% and 45%, depending upon the farm's size. These estimates are based upon the assumption that input and crop prices will remain at about the same levels which prevailed in 1973. It does not appear as though the group of non-potato farmers that currently have one or three hectares of land will earn incomes of Q1000. Before these farmers find it possible to earn a total income of Q1000, it will be necessary: (1) to achieve additional breakthroughs in cropping technologies; (2) to achieve a more favorable input product price relationship between prices of agricultural inputs and corn, bean, and wheat prices; or (3) to increase the size of the typical highland farm to a minimum of four hectares.

The Potato Farmer With One Hectare of Land

Categories 1 and 2 also presented information on the effect of different amounts of savings and provision of credit for the potato farmer with one hectare of crop land. Solutions for potato farmers in Categories 1 and 2 were presented in Sets 2A, 2B, 3A, 3B, 5, and 6. Sets 2A, 2B, and 5 presented solutions in which potato farmers were given a low level of vegetable knowledge. Sets 3A, 3B, and 6 presented solutions in which potato farmers were given a high level of vegetable knowledge. In all these resource sets, vegetable production was limited to one cuerda, or 0.04 ha, because it is regarded as a sideline and because vegetables are usually grown on quite small plots of land. As a result of this decision to limit production of vegetables to one cuerda, the solutions for farmers with a high level of vegetable knowledge are quite similar to solutions for those with a low level of vegetable knowledge, although income levels tend to be about Q30-Q50 higher for farmers with the higher level of vegetable knowledge. Since vegetable production is regarded as a sideline requiring special land, and because the solutions for farmers with a high level of vegetable knowledge are quite similar to the solutions in which farmers have a low level of vegetable knowledge, only those solutions in which the farmer has a high level of vegetable knowledge will be considered here. Consequently, this discussion will be confined to the results presented in Resource Sets 3A, 3B, and 6 of Categories 1 and 2.

In Sets 3A and 3B of Category 1, a severe shortage of savings was observed to be the potato farmer's most serious production constraint. Giving the farmer access to the Government's crop specific credit program in Set 6 of Category 2 relieves this savings constraint somewhat, although the shadow prices on savings of Q1.20 and Q0.91 for solutions with crop knowledge levels of TL2 and TL3, respectively, indicate that the farmer could have used still more credit. The major effects of giving the farmer Q100 additional savings in Set 3B and credit in Set 6 are: (1) to allow the farmer to increase his levels of total and crop income; and (2) to use more of his land for crop production. Table 6.4 presents information on the percent of land devoted to crop production in these nine solutions.

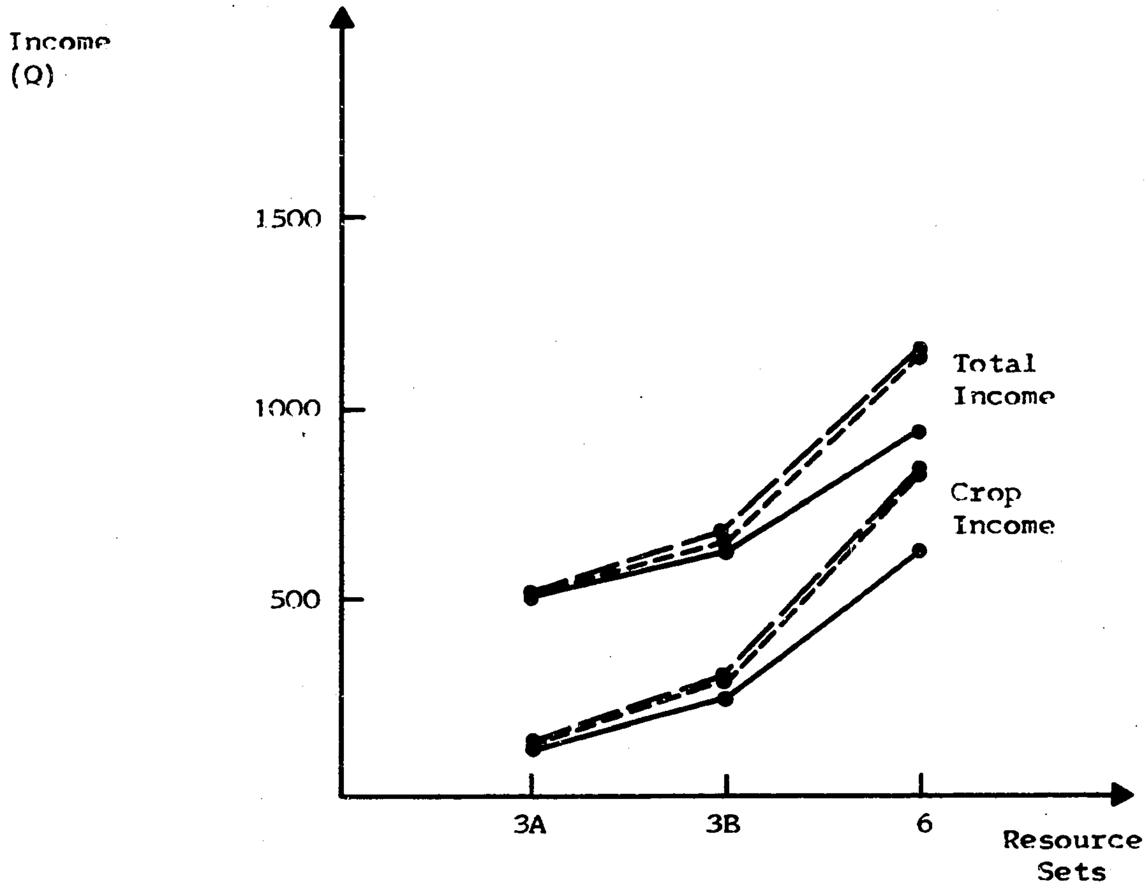
In Set 3A, the farmer's shortage of savings was so acute that he used only between 7% and 34% of his total land area for crop production. In Set 3B, the additional Q100 savings allowed him to increase this to between 21% and 55%. In Set 6, with Government credit, he was able to use 100% of his land for crop production in all three solutions.

Figure 6.6 shows how the farmer's levels of total and crop income increase as his amount of working capital is increased, thereby permitting him to use more of his land for crop production. The level of total income in Set 6 increases by between 73% and 121% (depending on the level of crop knowledge) over the level of total income the farmer earns in Set 3A with only Q50 savings. The percent of income earned from sale of crops increases from 21% in

Table 6.4. The percent of land used to produce crops in Resource Sets 3A, 3B, and 6

Resource Set	TL1	TL2	TL3
3A	9	34	7
3B	32	55	21
6	100	100	100

Set 3A to 42% in Set 3B to 71% in Set 6. The farmer in Set 6 with a crop knowledge level of TL2 or TL3 earns a total income of approximately Q1,150. About Q850 of this total comes from sale of crops. Therefore, we see that the potato farmer with one hectare of land is able to reach the target level of Q1000 total income given 1973 input and crop prices. He would earn this amount by growing approximately 0.75 hectares of potatoes, one cuerda of green onions (0.04 ha) and about 0.21 hectares of corn alone or milpa. If the farmer did not have the high level of vegetable knowledge which permitted him to grow green onions and carrots, he could have earned a total income of Q1,100 by growing 0.75 hectares of potatoes and 0.25 hectares of corn alone or milpa. Either way, the farmer is able to achieve a total income of over Q1000.



Semi-fixed Resources

Savings	50	150	50
Credit	None	None	Gov't
Ha. of land	1	1	1
Local laborers available	10	10	10

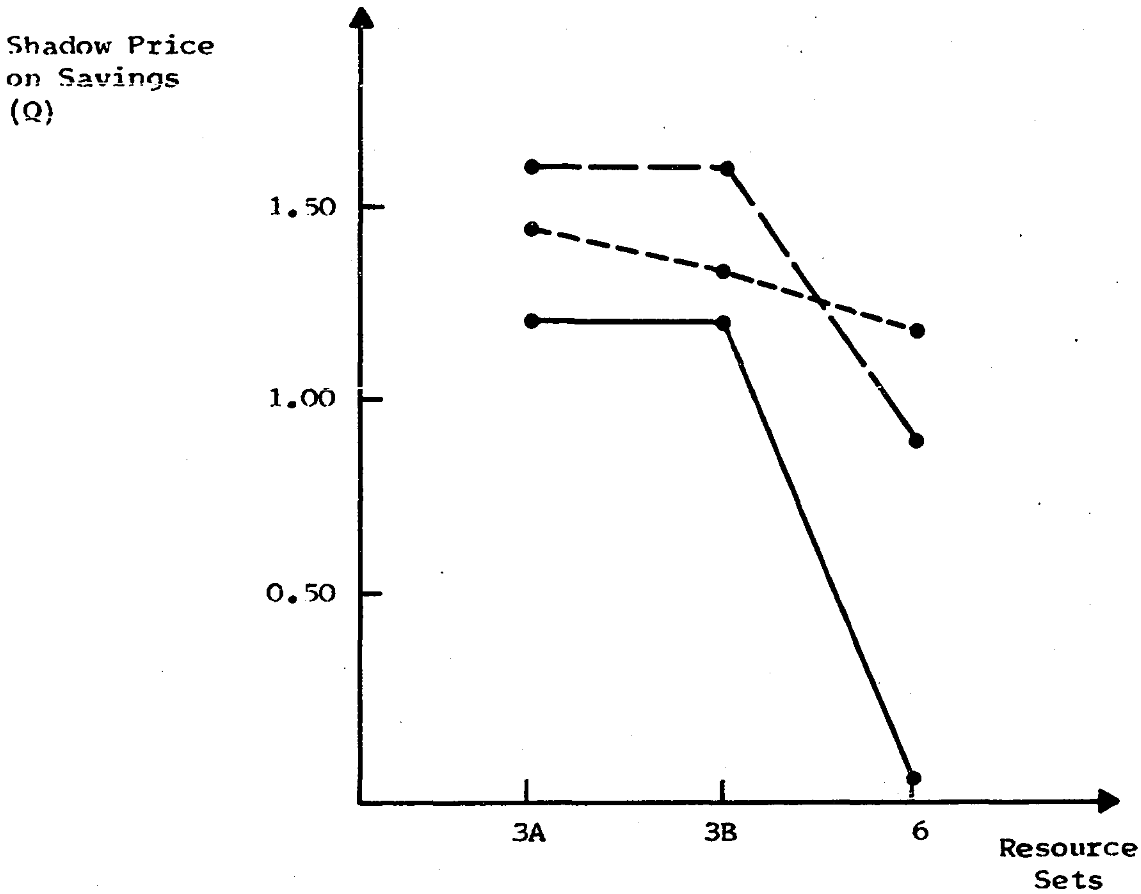
——— Crop knowledge level 1
- - - - Crop knowledge level 2
— — Crop knowledge level 3

Figure 6.6. Levels of total and crop income in Resource Sets 3A, 3B, and 6

Figure 6.6 also presented information on the amounts of total and crop income which could be earned with different levels of crop knowledge. Notice in Sets 3A and 3B that the farmer earns approximately the same amount of total and crop income with all three levels of crop knowledge. This is because a shortage of working capital prevents the farmer from fully utilizing the knowledge he has. In Set 6 where the farmer has Government credit, this constraint is eased. This causes total income earned to increase and also results in an increase in the spread between incomes earned with different levels of crop knowledge. We will observe in the next section that when the farmer has three hectares of land, this spread is much larger. The spread is larger on the three hectare farm, because the one hectare farm is not large enough to fully employ the family. Knowledge of new technologies cannot benefit the farmer very much if he is spending a large percentage of his time selling labor at 7.5¢ per hour. The farmer needs more than one hectare of land if he is to be fully employed on his own farm, and he needs to be fully employed on his own farm if he is to receive maximum benefits from a program of technical assistance which teaches him about new technologies.

Providing the farmer with credit allows him to use 100% of his land, and, consequently, land becomes a limiting factor for the one hectare potato farmer in Resource Set 6. In Sets 3A and 3B, the farmer had not been able to use all his land and shadow prices on land had, consequently, been zero, while the shadow price on savings was very high. Figure 6.7 demonstrates how the shadow price on savings is reduced in Set 6 when land becomes a limiting factor. The shadow price on savings is reduced in Set 6, because in Resource Sets 3A and 3B savings had been the only limiting factor. The shadow price on savings of Q0.05 (TL1) indicates that the amount of credit provided by the Government's crop specific credit program was adequate for all farmers who used the production technology requiring a crop knowledge level of TL1. The higher shadow prices on savings for solutions in which the farmer was given a crop knowledge level of TL2 and TL3 indicate that if farmers adopt the newer technologies which are currently being used by only the best farmers and on demonstration plots, it will be necessary to raise the average size loan made to potato farmers.

It is interesting to note that onions are grown in all the solutions considered for these three groups. In one case, onions even displace potatoes due to an extreme shortage of savings. This is not a particularly surprising result, because it has long been recognized that per hectare income and employment opportunities are great in vegetable production. The fact that onions have the ability to compete with and displace potatoes indicates that onions (and other vegetables, too) are just as profitable as potatoes and hold similar potential for allowing families to earn comparatively large incomes on comparatively small farms. Since land is such a severe constraint on most of the altiplano, many people have suggested that the Government should encourage development of cool season



Semi-fixed Resources

Savings	50	150	50
Credit	None	None	Gov't
Ha. of land	1	1	1
Local laborers available	10	10	10

———— Crop knowledge level 1
- - - - Crop knowledge level 2
— — — Crop knowledge level 3

Figure 6.7. Shadow prices on savings in Resource Sets 3A, 3B, and 6

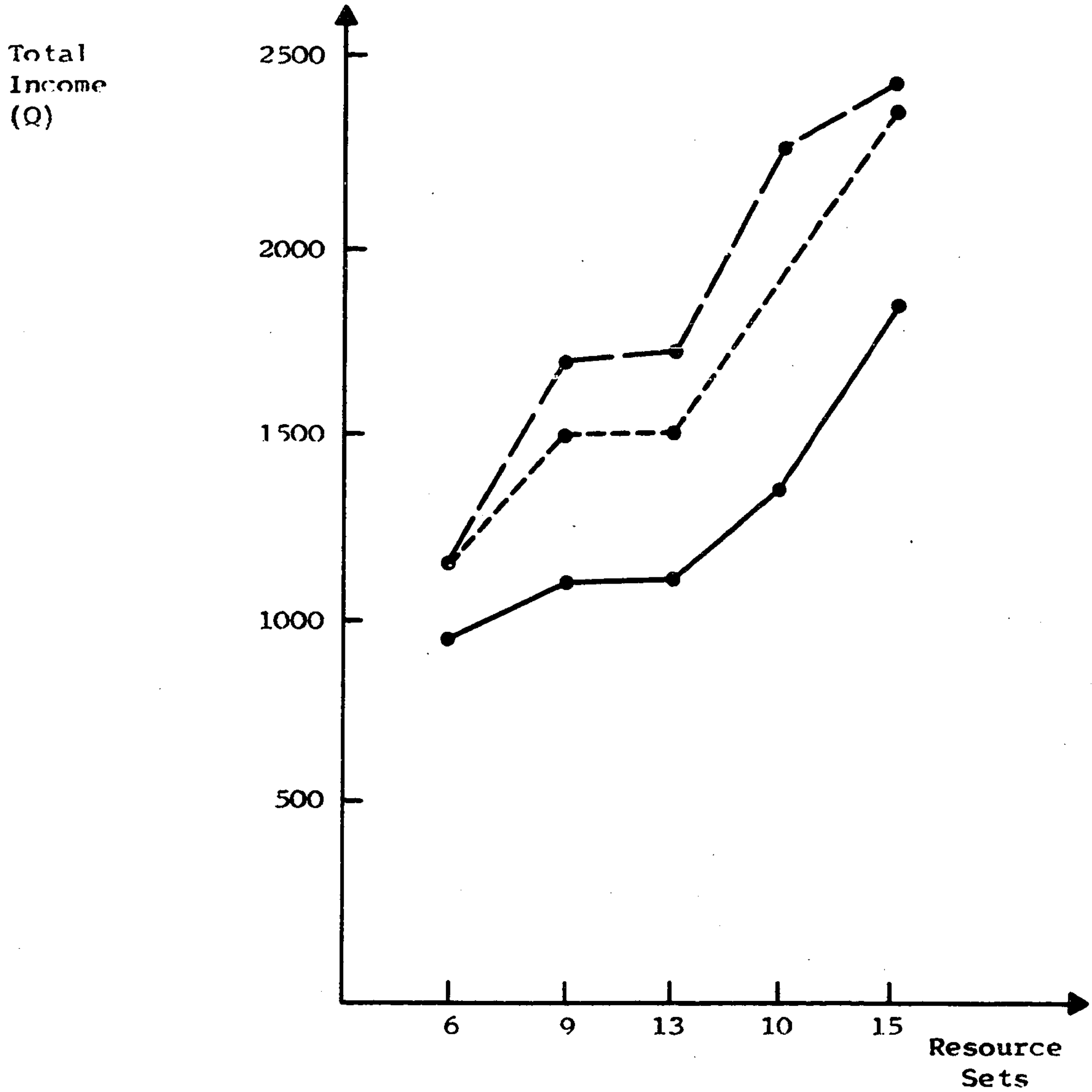
vegetable production on the altiplano as part of an agricultural and occupational diversification program designed to begin moving farmers out of corn, wheat and milpa production. This is a good idea, but one must realize that: (1) vegetable prices are quite unstable; and (2) it is quite easy to have an excess supply problem with vegetables because production per hectare is so high. Consequently, vegetable production, like potato production, can only be lucrative for a fairly small number of farmers. Any programs designed to stimulate production of potatoes or vegetables must take this potential oversupply problem into account. If vegetable production is increased through a vegetable production program, it will probably also be necessary to combine the production efforts with a vegetable marketing program, whereby part of the increased vegetable production could be exported to other Central American countries.

As population and income levels rise in Guatemala and in Central America, there should be some modest increases in demands for cool season fruits and vegetables which could be met by a well-planned program of agricultural diversification. Such a program would only benefit a small percentage of highland farmers, but even if it benefited only 1% or 2% of highland farmers, it would at least take 1% or 2% of the total population and a very small percentage of total land area out of corn, wheat and milpa production, thereby reducing both the number of traditional crop farmers and the potential supply of traditional crops. This is an important consideration, because as farmers begin to adopt higher yielding technologies for traditional crops, the supply of these traditional crops will be increased. Some of the increased supply will be needed to feed a growing population, but if yields increase dramatically over a short period of time, there is a danger that the supply of traditional crops could increase faster than the demand. This problem of over-supply may turn out to be an important one. The results presented in Chapter IV show us that per hectare production of corn, milpa, wheat, and potatoes could practically be doubled if all farmers decided overnight to adopt production activities which require a crop knowledge level of TL2. It is important that the Government monitor the success of the Basic Grains Program in promoting the use of new technologies. If the Basic Grains Program is successful in spreading adoption of new technologies to a large percentage of small farmers, plans need to be made now to devise programs which will: (1) provide employment for farmers who will have to leave traditional agriculture to allow the typical small farm size to increase; and (2) to plan and implement an agricultural diversification program which will divert land from traditional crop production. Agricultural diversification needs to be carefully planned to assure Guatemala of an adequate supply of traditional crops while at the same time taking care to avoid a problem of overproduction.

The Potato Farmer With Three Hectares of Land

This discussion, like the preceding one, will limit itself to those resource sets from Categories 3 and 4 in which the farmer is assumed to have potato land and a high level of vegetable knowledge. Consequently, only Sets 9, 10, 13 and 15 will be discussed here. These resource sets examine the effect of: (1) having either one or three hectares of potato land; and (2) being able to hire either zero or ten local laborers to assist with crop production tasks. In Sets 9 and 13, the farmer is given one hectare of potato land. In Set 9, he is not allowed to hire local labor, while in Set 13, he may hire up to ten men in any given quarter. In all other respects, Sets 9 and 13 are identical. The results for these two sets are very similar, because availability of hired labor is not very important for the three hectare farmer with only one hectare of potato land. In Sets 10 and 15, the farmer is allowed to grow up to three hectares of potatoes. In Set 10, he cannot hire local labor to assist with crop production tasks. This is a fairly serious constraint for the three hectare potato farmer. In Set 15, this constraint is eased and he is allowed to hire up to ten local laborers in each quarter.

In the preceding section, it became apparent that potatoes are a very lucrative crop. In this section, we will investigate just how lucrative potatoes can be for a farmer with three hectares of crop land. Figures 6.8 and 6.9 present information on the levels of total and crop income which can be earned from potato production

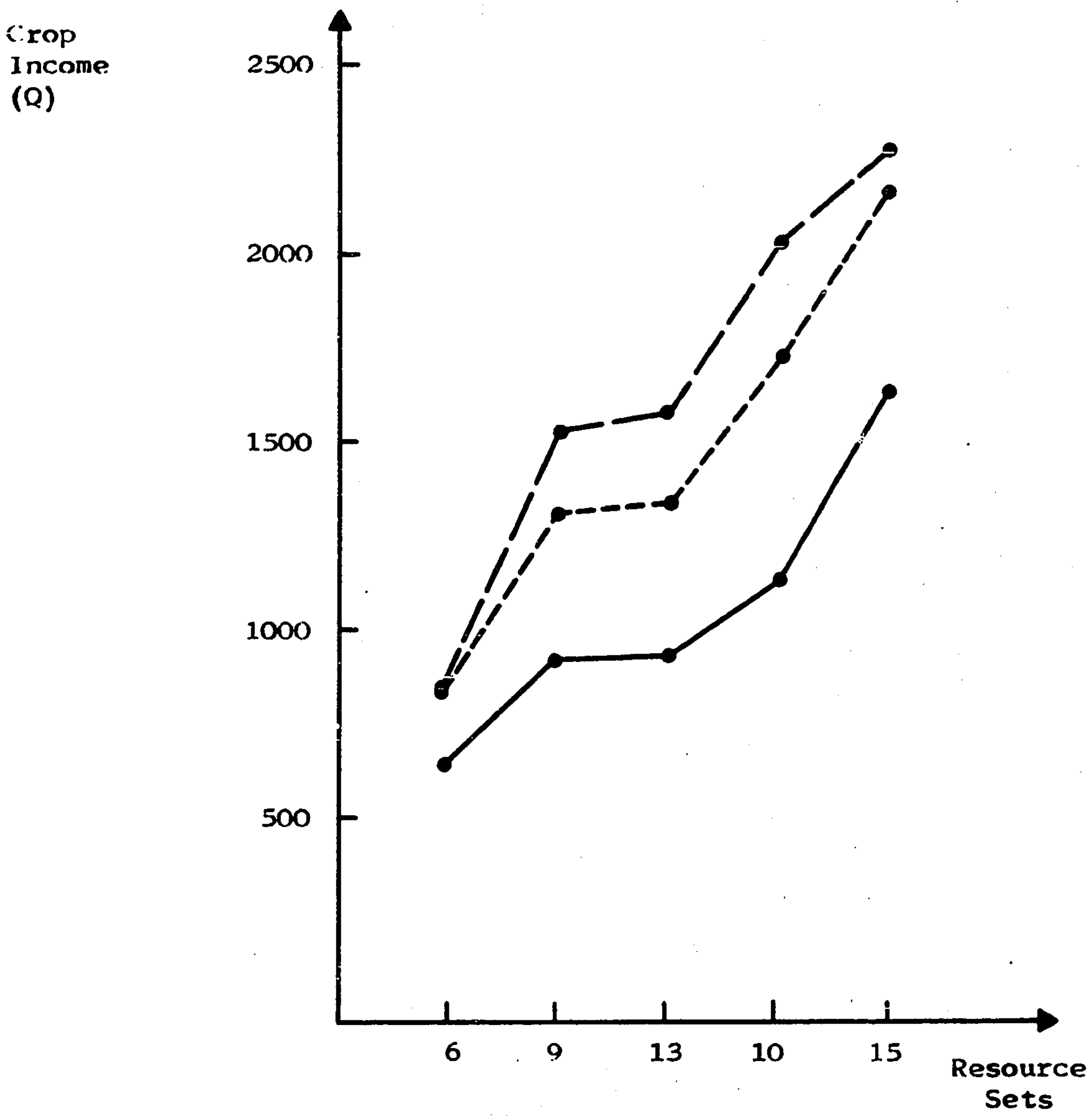


Resources

Ha. of potato land	1	1	1	3	3
Total ha of land	1	3	3	3	3
Local laborers available	10	0	10	0	10

——— Crop knowledge level 1
- - - - Crop knowledge level 2
— — Crop knowledge level 3

Figure 6.8. Levels of total income in Resource Sets 6, 9, 13, 10, and 15



Resources

Ha. of potato land	1	1	1	3	3
Total ha of land	1	3	3	3	3
Local laborers available	10	0	10	0	10

——— Crop knowledge level 1
- - - - Crop knowledge level 2
— — Crop knowledge level 3

Figure 6.9. Levels of crop income in Resource Sets 6, 9, 13, 10, and 15

on the three hectare farm. These figures also present information on the levels of income that were earned on a one hectare potato farm, Resource Set 6. Set 6 is included here to provide us with a basis of comparison between results for the farmer with one hectare of potato land and results for the farmer with three hectares of potato land.

As was mentioned above, farmers in Sets 9 and 13 have three hectares of crop land of which only one hectare is suitable for potato production. As can be seen from Figures 6.8 and 6.9, there is not much difference in the levels of total income the farmer can earn from Sets 9 and 13, and crop income stays at about 88% of total income for both groups. The availability of hired labor in Set 13 turns out to be relatively unimportant with respect to the levels of total and crop incomes which are earned. The farmer in Set 13 hires an average of 21 days' labor in second quarter, but this is the only quarter in which labor is hired. This additional labor is used to increase production of milpa on hilly lands by between 0.2 and 0.6 hectares, thereby allowing the farmer to use his entire three hectares of land for crop production. Being able to hire labor permits the farmer in Set 13 to more fully utilize the land and labor resources he has been given. The farmer in Set 13 uses all his land for crop production, whereas in Set 9, he lets an average of 0.42 hectares lie fallow due to the shortage of second quarter labor. The farmer in Set 13 is also more nearly fully employed on his own farm than the farmer in Set 9. In Set 13, the farmer sells only 701 hours of labor locally, a decrease of 37% from the average of 1109 hours sold locally in Set 9. The only differences between the solutions in Sets 9 and 13 are the three that have been mentioned here: (1) the percentage of total land that is used for crop production; (2) the number of local labor hours that are hired; and (3) the number of local labor hours that are sold. The net effect of these differences on the level of total income is essentially to cancel each other out. Total incomes in Set 13 are only marginally higher than total incomes in Set 9.

The farmer grows one hectare of potatoes, one cuerda of onions and either milpa or corn alone in all six solutions of Resource Sets 9 and 13. When he has a crop knowledge level of TL1, he also grows wheat. Other than a shortage of second quarter hired labor in Set 9 (where he is not allowed to hire labor), the only binding constraints for these two sets are valley land and potato land. The shadow price on potato land averages Q715, and the shadow price on valley land is between Q83.05 and Q166.32. The farmer has access to the Government's crop specific credit program and working capital is, consequently, not a constraint in any of these six solutions. Now that the farmer has an adequate supply of working capital, and enough land to fully employ the entire family, technical assistance is capable of having a much greater impact on the level of total income. Figure 6.8 shows that the difference in the amount of total income earned with crop knowledge levels TL1 and TL3 has increased to about Q600 in Resource Sets 9 and 13. This is approximately Q400 more than the difference in income levels observed in Set 6 where the farmer had only one hectare of crop land, and demonstrates the importance of combining knowledge of new technologies with credit and an adequate farm size.

Availability of hired labor was not very important in Resource Sets 9 and 13, because potatoes have a different pattern of labor requirements than the other traditional crops. This difference makes potato production quite complementary with corn, milpa, or wheat production on the farm with only one hectare of potato land. Potatoes require the most labor during second quarter, a period of fairly low labor requirements for corn, milpa, and wheat. Corn, milpa, and wheat require large amounts of labor during fourth quarter when potatoes require no labor whatsoever. By combining potatoes with corn, milpa or wheat production, the farmer is able to counterbalance peak labor requirements between crops and, therefore, to farm more land with a fixed labor supply.

In Resource Set 10, the farmer's amount of potato land is increased to three hectares, while local labor availability is reduced to zero men. This causes a very severe seasonal labor shortage, because the farmer would like to grow three hectares of potatoes, but is constrained from doing so by a shortage of labor in second quarter. The shadow prices on second quarter labor in Set 10 range between Q0.713 and Q1.17 per hour reflecting the seriousness of this shortage. Only potatoes are grown in Set 10. The farmer grows 1.835 hectares of potatoes in all three solutions. The shortage of second quarter labor is so severe that although the farmer has a high level of vegetable knowledge, no vegetables are grown. This occurs because vegetables, like potatoes, require a fairly large amount of second quarter labor. Although the shortage of labor is a serious constraint, the farmer is able to grow 1.835 ha of potatoes which increases his total income by an average of about Q450 over levels of total income earned in Sets 9 and 13. The spread between income earned with different levels of crop knowledge is really very large in Set 10. Farmers with a crop knowledge level of TL1 earn a total income of about Q1375, while farmers with a crop knowledge level of TL3 earn a total income of about Q2275. This means that having a crop knowledge level of TL3 allows the potato farmer in Set 10 to earn an additional Q900. Thus, the farm level benefit of a technical assistance program is potentially Q900 for the potato farmer in Set 10.

In Set 15, the farmer is allowed to hire labor. He hires an average of 23 days' labor in first quarter and 89 days' labor in second quarter. This hired labor allows the farmer to use his entire three hectares of land for crop production. Potato production is increased from 1.835 ha in Set 10 to an average of 2.300 ha in Set 15. In addition to potatoes, the farmer grows either wheat, milpa, or corn alone and a cuerda of onions in each solution.

The primary constraints in Set 15 are savings and land. More working capital is needed to increase production of potatoes when the farmer has a crop knowledge level of TL2 or TL3. The shadow price on savings with a crop knowledge level of TL2 or TL3 is Q1.20 and Q0.91, respectively, indicating that the shortage of working capital is fairly restrictive. The shadow price on valley land ranges between Q88.79 and Q514.66. The shadow price of Q514.66 reflects the fact that the most productive potato activity requires all valley land. This shadow price on valley land is fairly high, because the farmer has the other resources which he would need in order to devote additional valley land to potato production.

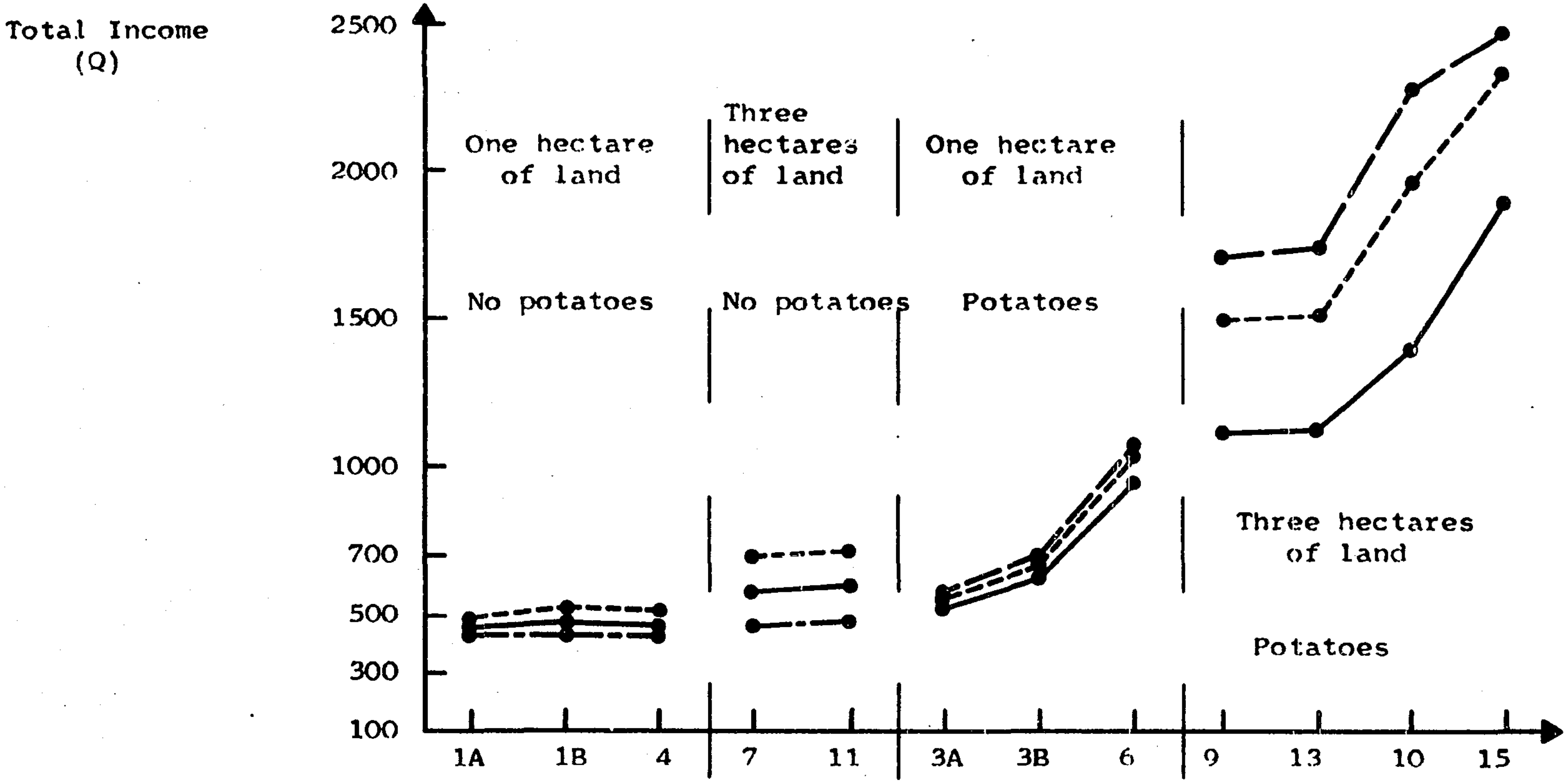
The farmer's income in Set 15 increases to an average level of Q2,237.89. This is an increase of about Q360 over the average level of income earned in Set 10. Figures 6.8 and 6.9 show us that both the levels of total income and crop income have a spread of about Q580 in Set 15. Therefore, the farm level effect of a technical assistance program which increases crop knowledge from TL1 to TL3 is about Q580. It is also interesting to note that crop income in Set 15 remains at about 88% of total income. This is approximately the same percentage that was found in Sets 9, 13, and 10.

CHAPTER VII. SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The Farm Level Effects of the Basic Grains Program

The results and conclusions presented in Chapters V and VI are summarized in this chapter. The major conclusions are related to how changes in the farmer's resource base influence his income and the extent to which he is employed on the farm. The specific resources which are assigned different levels in the various resource sets considered here are: savings, credit availability, knowledge of new technologies, land, local labor availability, and potato land.

One of the main interests in this study has been to investigate the potential effect of the Basic Grains Program upon the level of family income. Figure 7.1 is helpful in summarizing the results of this investigation. This figure shows how the level of family income is increased as the farmer's resource set is expanded. In Figure 7.1, resource sets are identified by number (1A, 1B, 4, etc.) along the horizontal axis. These resource sets are simply groups of resources which serve to identify the levels of the major constraints in the linear programming model. The levels which these resources (or constraints) take on are presented in a column below the number of each resource set. For example, the levels of the key resources in Set 1A are: zero hectares of land suitable for potato production; one hectare of crop land in total; no access to a source



Resources	1A	1B	4	7	11	3A	3B	6	9	13	10	15
Ha. of potato land	0	0	0	0	0	1	1	1	1	1	3	3
Ha. of land	1	1	1	3	3	1	1	1	3	3	3	3
Credit	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Savings	50	150	50	50	50	50	150	50	50	50	50	50
Local laborers available	10	10	10	0	10	10	10	10	0	10	0	10

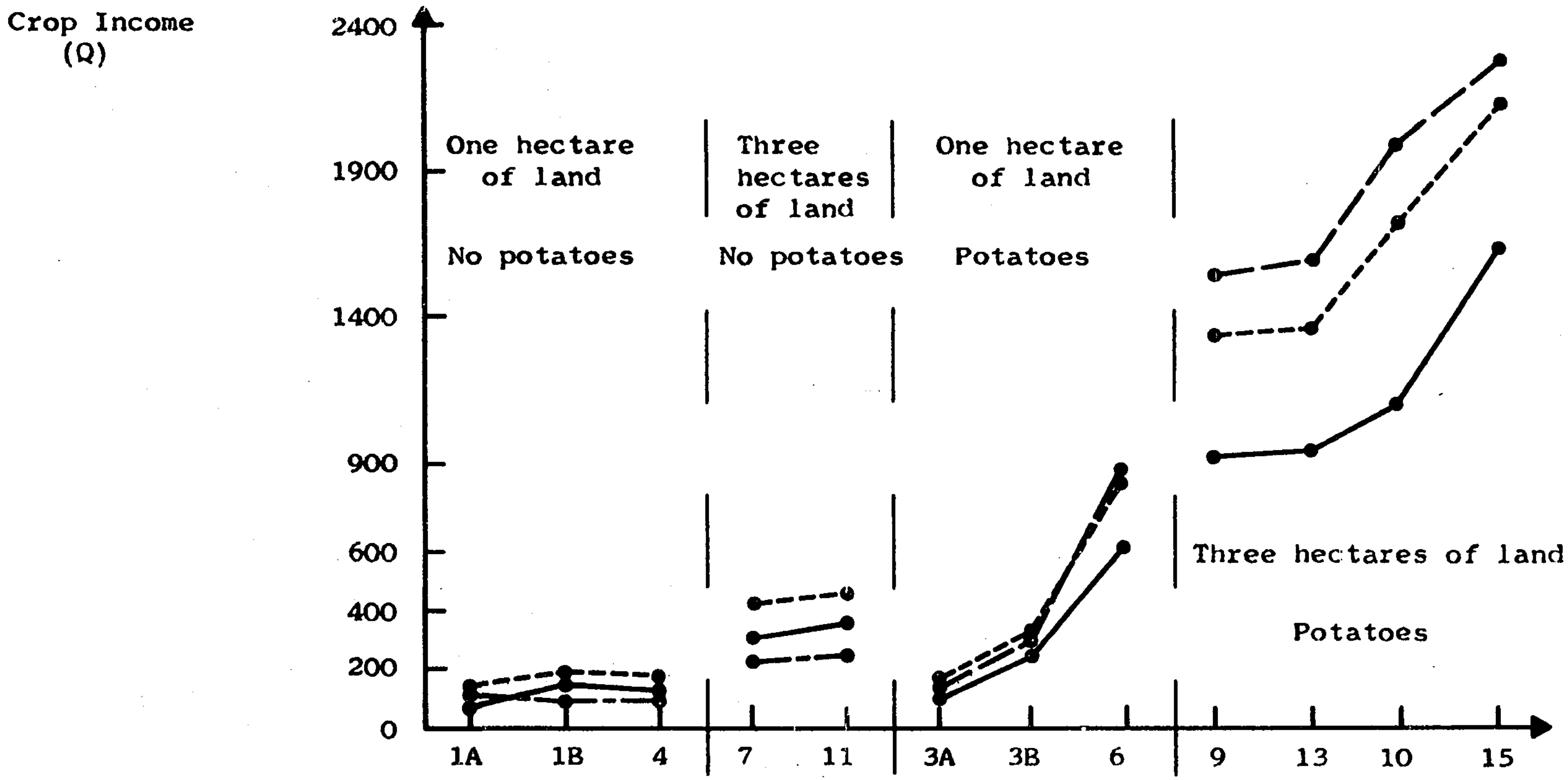
———— Crop knowledge level TL0 — — — — Crop knowledge level TL2

———— Crop knowledge level TL1 —— —— Crop knowledge level TL3

Figure 7.1. Levels of total income for 12 different resource sets

of credit; Q50 savings which are used for working capital; and a maximum of ten local laborers who could assist the family with crop production tasks in each quarter. The three levels of total income specified for each resource set in Figure 7.1 were generated by parameterizing the level of crop knowledge within each group. Note that for resource sets in which the farmer does not have potato land, the levels of crop knowledge used to generate solutions are levels TL0, TL1, and TL2. Level TL3 is not included because it is only used to grow potatoes. For sets in which the farmer does have potato land, the levels of crop knowledge used to generate solutions are levels TL1, TL2, and TL3. Level TL0 is not included here because high yield potato activities require a crop knowledge level of TL1 or higher. If the farmer were given a crop knowledge level of TL0, he could not grow potatoes, and his levels of total income, crop income, etc. would be the same as if he had not been given potato land. It is important to remember that if a farmer has crop knowledge level TL2, he will also have levels TL1 and TL0. With crop knowledge level TL2, the farmer can elect to produce any crop activity that requires a crop knowledge coefficient for levels TL2, TL1, or TL0, although he could not elect to produce an activity that requires a crop knowledge level of TL3.

Figures 7.1 and 7.2 combine the results which were presented in independent sections of Chapter VI. They summarize the information presented earlier and allow the reader to readily compare and contrast the position of the one and three hectare potato farmer



Resources	1A	1B	4	7	11	3A	3B	6	9	13	10	15
Ha. of potato land	0	0	0	0	0	1	1	1	1	1	3	3
Ha. of land	1	1	1	3	3	1	1	1	3	3	3	3
Credit	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Savings	50	150	50	50	50	50	150	50	50	50	50	50
Local labor available	10	10	10	0	10	10	10	10	0	10	0	10

Crop knowledge level TL0
Crop knowledge level TL1
Crop knowledge level TL2
Crop knowledge level TL3

Figure 7.2. Levels of crop income for 12 different resource sets

with the position of the one and three hectare non-potato farmer. Let us begin this review of major conclusions by considering the role which credit availability plays on the one hectare non-potato farm.

The importance of credit for the non-potato farmer was investigated in Sets 1A, 1B, and 4. As can be seen in Figure 7.1, the amount of total income which the farmer in Set 1A earns ranges between Q443.47 and Q492.07. When the farmer is given credit in Set 4, his total income is increased to between Q446.68 and Q521.96 depending upon his level of crop knowledge. If the farmer has a crop knowledge level of TL0, the increased income which he earns with credit is only Q3.00 greater than he earned without credit. If the farmer has a crop knowledge level of TL2, credit allows the farmer to earn about Q30 higher total income than he could earn without credit. Clearly, credit does not help the farmer in Set 1A to earn a very significant increase in total income. Why is this? The answer is that the farmer in Set 1A is spending only about 20% of his total labor time on crop production. The rest of his time is spent selling labor. He produces crops on the entire one hectare of land which he has been given, but one hectare is not enough land to fully employ a family of four with a total labor supply equivalent to 2.1 adult male workers. The results presented in Figure 7.1 indicate that neither credit nor technical assistance can substantially benefit a farm family with only one hectare of crop land.

When the family's amount of crop land is increased to three hectares in Sets 7 and 11, the farmer is able to earn a total income of about Q480 with a crop level of TLO and a total income of about Q700 with a crop level of TL2. An income of Q480 is about Q37 higher than the income earned in Set 1A with a crop knowledge level of TLO and indicates that giving the farmer credit and an additional two hectares of land could increase total income by only about Q37. If, however, the farmer in Set 1A with a crop knowledge level of TLO was given an additional two hectares of land, credit, and technical assistance (which increases his level of crop knowledge to TL2), he could earn an income of about Q700. This is an increase of approximately Q256. The difference between Q256 and Q37 represents the farm level effect of giving the farmer more land, credit and technical assistance. All three ingredients are needed if the farmer is to achieve a substantial increase in income. Credit by itself or technical assistance by itself, or credit and technical assistance without land will not be enough.

Figure 7.2 presents information on the levels of crop income which farmers can achieve with different levels of crop knowledge. We can see by comparing Figures 7.1 and 7.2 that on the one hectare non-potato farm only about 20-35% of total income comes from sale of crops. The remainder comes from labor sale income. On the three hectare non-potato farm, the percentage of crop to total income is increased to about 45-65%. The non-potato farmer with three hectares of land experiences a shortage of labor in fourth quarter, but he still sells a great deal of labor in the other three quarters. Although the amounts of crop income are lower than the amounts of total income, Figure 7.2 presents the same pattern observed in Figure 7.1. Farmers need land, credit and technical assistance if they are to substantially increase their levels of crop income.

The role of credit alone as a means of helping the potato farmer with one hectare of land is presented in Sets 3A, 3B, and 6. Potatoes require substantially larger amounts of working capital than corn, wheat, or milpa production. Potatoes also have a higher per hectare value of production than do corn, wheat, or milpa. Consequently, providing a farmer with credit for potato production has a comparatively greater impact on family incomes than providing the farmer with credit for production of other traditional crops. This difference can be seen quite clearly in Figure 7.1.

In Set 3A, the farmer has one hectare of land that can be used to grow potatoes. The level of total income which the farmer earns is between Q517.24 and Q526.81, depending upon his level of crop knowledge. The level of crop knowledge has only a marginal effect on total income here because the farmer experiences such a tremendous shortage of working capital. In Set 6, the farmer is given credit and his level of total income increases to between Q949.22 and Q1154.27. Providing the farmer with credit alone is therefore capable of increasing total income by approximately Q430-Q630. The spread between the total income earned by a farmer with crop knowledge levels TL1 and TL3 is increased from about Q30 in Resource Set 3A to about Q200 in Resource Set 6. Thus, we see that while credit alone is quite important, combining credit and technical assistance allows farmers to achieve significantly higher levels of total income. Technical assistance could potentially yield even higher returns to the potato farmer in Set 6, because even though he has credit, the farmer experiences a shortage of working capital. This shortage occurs because the amounts of credit provided by an average BANDESA loan in 1973 were not sufficient to supply all the working capital needed by the most advanced potato activities (those activities requiring crop knowledge levels of TL2 and TL3). It must, however, be pointed out that the amount of working capital provided by BANDESA was sufficient for the potato activity used by most farmers in 1973 (the activity requiring a crop knowledge level of TL1).

Potato farmers in Set 6 experienced shortages of land, particularly valley land, as well as a shortage of working capital. Consequently, in Sets 9 and 13, the farmer was given an additional hectare of both hilly and valley land with the provision that only one of his total three hectares of land could be used for potato production. The result was to increase the level of total income in Set 13 to Q1,724.85 for a farmer with a crop knowledge level of TL3, and to Q1,109.61 for a farmer with a crop knowledge level of TL1. Now the spread between income earned with crop knowledge levels TL1 and TL3 has increased to over Q600, and the amount of total income which the farmer with a crop knowledge level of TL3 could earn has increased by almost Q1,200 over the amount of total income he could earn in Resource Set 3A.

In Sets 10 and 15, the farmer's amount of potato land is increased from one to three hectares. The level of total income in Set 15 increases to between Q1,876.05 and Q2,459.32. The spread between incomes earned with crop knowledge levels TL1 and TL3 is now Q583.27, a slight reduction from the spread of over Q600 observed in Set 13, but still a very large amount. The level of total income earned by a farmer with a crop knowledge level of TL3 is now Q1,942.08 higher in Set 15 than in Set 3A with a crop knowledge level of TL1.

The progression of increasing incomes observed in Figure 7.1 illustrates the importance of providing the potato farmer with a combination of credit, technical assistance, additional land, and an adequate supply of local hired labor to assist with crop production tasks during peak periods. Credit alone can increase income by about Q400 on one hectare of land. Credit and technical assistance increase family income by about Q600 on one hectare of land. One hectare of potato land on a three hectare farm, credit and technical assistance increase income by about Q1,200. Three hectares of potato land on a three hectare farm, credit, and technical assistance increase income by about Q1,700. Three hectares of potato land on a three hectare farm, credit, technical assistance and an adequate supply of local hired labor increase family income by about Q1,950. All of these ingredients are important, but as was the case with the non-potato farmer, land is probably most important. This is again due to the fact that the one hectare farm is simply too small to fully employ a family with a total labor supply equivalent to 2.1 adult male farm laborers.

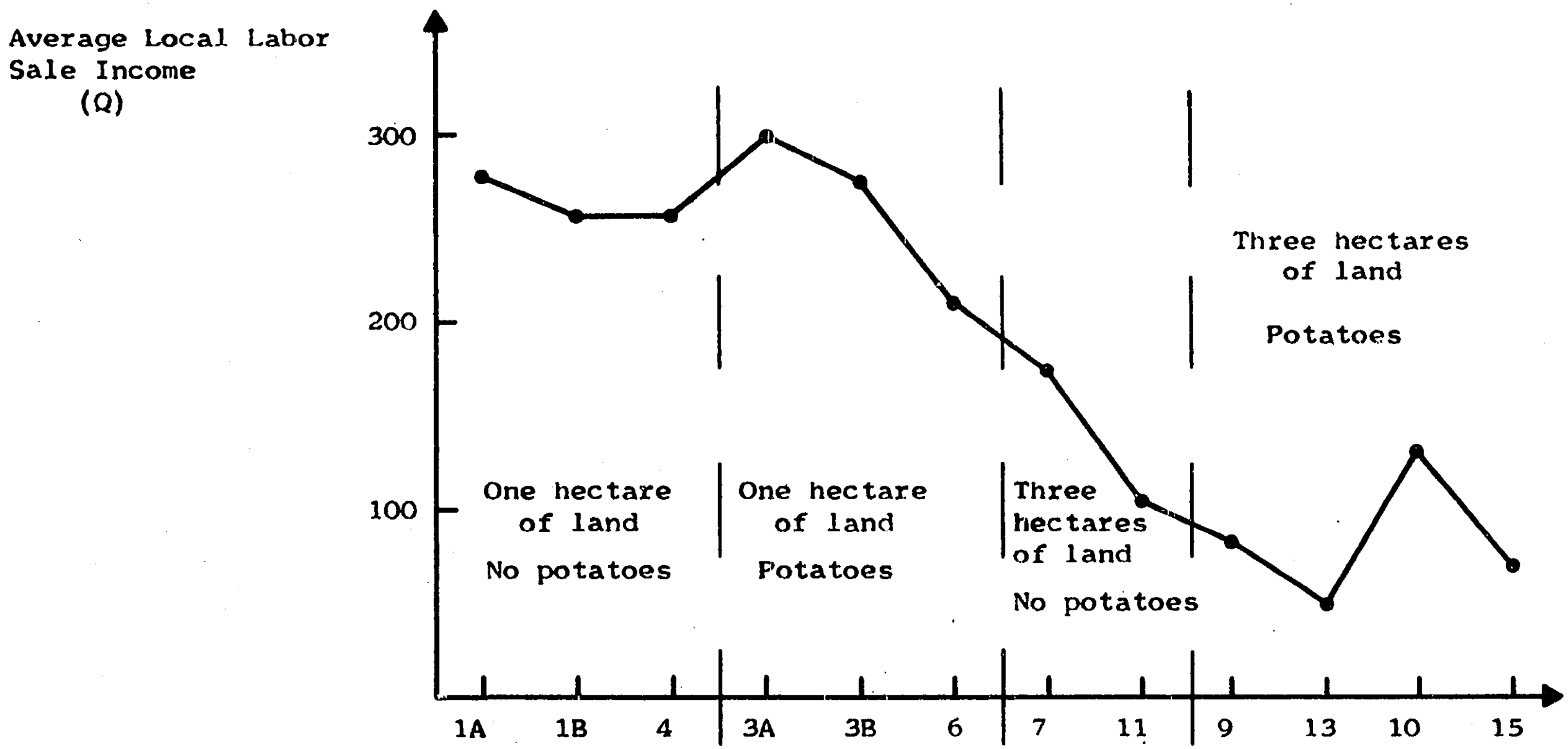
Before leaving this discussion of income levels which can be earned by potato farmers, it is necessary to make some qualifying observations. There is potential for some farmers to increase their incomes by adopting new potato production technologies and devoting more of their land to potatoes. The number of farmers who will be able to benefit from these new technologies is, however, quite small. Furthermore, the incomes farmers will actually earn are considerably overstated here. These results are conditional upon input and output price levels remaining at the levels specified in the model, or increasing in such a proportion that the net value of production per hectare remains as it was in 1973. It is very unlikely that this will happen because as the Basic Grains Program is successful in providing credit and technical assistance to small farmers, potato yields will increase and more land will probably be devoted to potato production. The supply of potatoes will be increased and this will cause average potato prices to decline. In Chapter IV, it was suggested that potato prices which had averaged Q4.75 per qq between 1966 and 1971 will probably decline to around Q3.00 per qq during the next five or six years. An average price of Q3.00 per qq would reduce the total income levels presented in the model considerably.

The fairly high average potato prices which have prevailed in the past can be attributed to the fact that potatoes have tended to be a specialty crop grown by only a small percentage of all farmers. The 1964 Agricultural Census (Dirección, 1971) estimated that potatoes were grown on only 3,071 hectares as compared with corn which was grown on 437,555 hectares. Thus, the land devoted to potato production was only about 0.7% of the land devoted to corn production in 1964. Similarly, the Census estimated that potatoes were grown on 12,878 farms while corn was grown on 320,788 farms. This means that only four farmers grew potatoes for every 100 farmers who grew corn. There are three main reasons why potatoes were grown by such a small number of farmers and on such a small amount of land even though they are a very lucrative crop. First, potatoes cannot be grown everywhere. To achieve high yields, the farmer must have land that is agronomically, altitudinally and climatically appropriate for potato production. Second, potatoes require relatively large amounts of working capital, and many farmers do not have enough capital to make it worthwhile to try and produce potatoes in a technified manner. Third, potatoes are quite a risky crop. Risk from disease or insect damage can be serious and risk from price fluctuations is even more serious. In spite of the fact that the number of farmers who grow potatoes is quite small, production in a given year can be quite high. Thus, although the average level of potato prices is quite favorable, potato prices are subject to large fluctuations, and this makes potatoes very risky for a farmer who does not have enough working capital to be able to take a large loss. This combination of a limited amount of appropriate land, a shortage of working capital, and high risk has resulted in potatoes being produced by only a small minority of farmers.

As was pointed out earlier, one of the effects of the Basic Grains Program will probably be to increase the supply of potatoes which should result in a decline in average potato prices. Thus, the income levels estimated by the model for potato farmers should be regarded as overestimates because the Basic Grains Program will relieve some of the constraints which were responsible in the past for there being such a high average potato price. Potatoes do, however, hold potential for increasing small farm incomes; vegetable production holds similar potential. Still, one must realize that potatoes and vegetables are not the answer to the problem of raising small farm incomes because potato and vegetable production can benefit only a small percentage of the total number of small farmers.

In earlier chapters, it was pointed out that another important goal of the Basic Grains Program was to increase employment on the small farm, thereby reducing the level of rural-urban migration. Therefore, the extent to which the family is fully employed on the farm is probably almost as important as the amount of income earned. During the earlier discussions of income levels earned by non-potato farmers on one hectare of land, the point was made that one hectare of land is not enough land to fully employ a family with a total labor supply equivalent to 2.1 adult male workers. Some of the model's main conclusions regarding this question of on-farm employment and underemployment have been summarized in Figure 7.3.

In Figure 7.3, the extent to which the farmer is fully employed on the farm has been represented in an inverse fashion by looking at the average amount of income the farmer earns from selling labor locally in each resource set. The reader will recall that local labor sales activities play two roles in the model. First, they provide an alternate and competing use for the farmer's labor hours. This competition forces crop activities to return the farmer at least as much income per hour worked as he could earn by selling labor locally. If a crop activity cannot do this, it will not be included in the optimal solution. Second, local labor sales activities allow the family to always be fully employed. Any labor which is not required for crop production activities or migratory labor sales activities is sold locally. The model implicitly assumes the family will be fully employed, and all income estimates generated by the model are telling us how much income the family would earn if it is fully employed. This assumption was built into the model because the study attempts to find the maximum income the small farmer can earn, and also because Manger-Cats (1966) has estimated that small farmers are nearly fully employed due to the fact that they devote considerable amounts of labor to off-farm labor sales activities.



Resources	1A	1B	4	3A	3B	6	7	11	9	13	10	15
Ha. of potato land	0	0	0	1	1	1	0	0	1	1	3	3
Ha. of land	1	1	1	1	1	1	3	3	3	3	3	3
Credit	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Savings	50	150	50	50	150	50	50	50	50	50	50	50
Local labor available	10	10	10	10	10	10	0	10	0	10	0	10

Figure 7.3. Levels of average labor sale income for 12 different resource sets

The order of the resource sets in Figure 7.3 has been altered from the order presented in Figures 7.1 and 7.2 in an attempt to emphasize the importance of farm size as a factor in determining the amount of labor that is sold locally. With the exception of this one change, however, Figure 7.3 is organized in the same way as were Figures 7.1 and 7.2.

In Resource Sets 1A, 1B, and 4 of Figure 7.3, we see that providing the one hectare non-potato farmer with credit causes an average reduction in local labor sales income of approximately Q20. This represents a reduction of about 267 hours or 33 days in the total amount of local labor sales. This means that providing the farmer with credit allowed him to increase on-farm employment by 33 days. In Sets 3A, 3B, and 6, we see that giving a farmer with potato land credit will reduce average local labor sales by approximately Q85 and hence will increase on-farm employment by about 142 days. Even with credit, however, the family in Group 6 is still earning approximately Q210 from local labor sales which means they are selling 350 days labor locally.

Giving the farmer more land in Sets 7, 11, 13, 10, and 15 causes the amount of labor sold locally to decline still more. Notice that average local labor sales are significantly higher in Sets 7 and 11 where the family was not allowed to hire local labor to assist with crop production during peak labor requirement periods. This occurs because labor shortages at certain peak periods cause a labor bottleneck which limits the amount of land that can be devoted to crop production. If the farmer can hire labor to relieve this bottleneck, he can increase the amount of land he has in crops and hence increase the total number of days he is employed on the farm (reduce the average number of days sold locally).

It is interesting to note that the farmer in Set 13 is able to spend considerably more time working on his own farm than the farmer in Set 11 who also has three hectares of land and can hire local labor to relieve bottlenecks caused by seasonal labor shortages. This occurs because of the complementarity mentioned earlier which exists between labor requirements for potato production and labor requirements for production of the other traditional crops.

The results contained in Figure 7.3 can probably best be summarized by one observation. Providing farmers with credit is important in allowing them to be more nearly fully employed on their own farms, but providing them with larger farms is even more important. Even on the three hectare farm in Resource Sets 13 and 15, the farmer and his family are not fully employed in spite of the fact that they farm the entire three hectares and can hire local laborers to relieve seasonal labor shortages. The farmer in Set 13 earns about Q50 selling labor locally which means he and his family spend about 83 days a year or 12.6% of the family's annual labor supply selling labor locally. This is probably an acceptable level for local labor sales. The family in Set 1A, however, spends about 447 days or 68% of its annual labor supply selling labor locally. This is probably not an acceptable level. If farmers are to be fully employed or nearly fully employed in traditional agriculture, the typical farm size will need to be expanded to three or more hectares.

One other question which the model sheds limited light upon is the question of the extent to which the Basic Grains Program might disrupt the seasonal migration of highland farmers who assist with harvest activities on coffee, cotton, and sugar cane farms. The results of the present analysis indicate that there will be no major interruption of this activity. The reason for this is that farms at present are not large enough to fully employ farmers, and so migratory labor sales are likely to continue. If farms were larger, the increased yields and incomes which the new technologies will make possible could change this. In all solutions generated by the model, however, the farmer sells the maximum amount of migratory labor allowed (120 days). This occurs for several reasons. For solutions in which the farmer has only one hectare of land, he has ample labor to allow him to produce crops and migrate the maximum amount, and so he migrates. For solutions in which the farmer has potato land, his labor shortages come in second quarter and do not conflict with migratory activities in third and fourth quarters; consequently, he migrates. For solutions in which the farmer is allowed to hire local labor to assist with crop production tasks, he can hire local labor at 7.6¢ per hour and earn 11¢ per hour by selling migratory labor; therefore, he migrates. The only solution in which migratory labor sales are brought into direct competition with crop activities is in Category 3. Resource Set 7 is one of the sets in Category 3 where this competition exists. In Set 7, the farmer does migrate the maximum allowed, but he does this because he has a shortage of valley land. Recall that valley land is required for the highest yielding corn, wheat, and milpa activities. The farmer has enough labor to migrate and produce crops on his valley land where he can use the newer technologies. He does not, however, have enough labor to also farm all his hilly land. Hilly land, the reader will recall, is not used with the newer high yielding technologies. As a result, part of his hilly land is left unused in two of the solutions for Set 7. As was mentioned in Chapter V when conclusions were presented for non-potato farmers in Category 3, the shadow prices on local hired labor indicate that the farmer came very close to diverting labor from migratory labor sales activities to cropping activities on hilly land. If there had been a conflict between migratory labor sales and cropping activities on valley lands, the farmer would have curtailed his migratory labor sales, but as it was, he migrated the full 120 days allowed by the model.

Suggestions for Further Research

This section has been divided into two parts. The first part deals with extensions of the present analysis and is essentially a series of additional questions or lines of study which could be analyzed using this model and this data. The second part identifies: (1) several types of basic data that would be very useful but which are presently unavailable; and (2) some general areas for future research.

Extensions of the present analysis

In this study, a profit maximizing objective function has been used to investigate the potential level of income a small farmer could earn if he were given credit and technical assistance. While the profit maximizing assumption was appropriate for the purposes of this study, one may question how realistic it is. Are small farmers primarily interested in maximizing profits, or is some other objective more important than profit maximization? An alternate objective function which is often suggested for small farmers is risk minimization. To the extent that small farmers engage in subsistence agriculture, it seems reasonable to assume that risk minimization is at least as important as profit maximization. Since small farmers in Guatemala are engaged in a type of agriculture which is not purely subsistence or commercial agriculture, it seems worthwhile to try and incorporate the goals of both profit maximization and risk minimization into the LP model. This could be done by including activities for home consumption of corn and beans in the model, because corn and beans are staples for most small farmers. Consumption activities would be constrained to ensure that the farmer is producing and consuming a given minimum amount of corn and beans. Crops consumed at home would be valued at market prices to guarantee that they are counted as part of the farmer's total income. Inclusion of this minimum consumption constraint would limit the farmer's choices of production activities, because he could not choose a set of production activities that did not include minimum production levels for corn and beans. It would be interesting to see how this constraint would alter the levels of crops produced, incomes earned and hours required for on-farm employment when compared with the solutions examined in the present analysis.

A second, but related, area for further research concerns the amount of credit the small farmer is willing to borrow. In this study, it was assumed that the farmer would borrow working capital as long as such borrowing allowed him to increase his net revenue, i.e., so long as the return from using an additional Quetzal of working capital exceeded the cost of borrowing it. If farmers are risk minimizers, however, they may not be willing to borrow this much working capital. They might instead borrow only up to a point where return from using working capital exceeded the cost of borrowing by an arbitrary amount, perhaps 15¢ per dollar borrowed. This 15¢ would represent a margin of safety to the small farmer. Studies have shown that some farmers in the United States have at times been reluctant to borrow working capital to the point where the shadow price on working capital falls to zero. Given the normal uncertainty associated with anything new, small Guatemalan farmers may be willing to adopt new technologies and borrow working capital needed for these new technologies, but they may be hesitant to borrow as much as lending agencies allow or as much as they would need to actually maximize profits. The effect of this hesitancy could be investigated by parameterizing the amount of working capital lending authorities are willing to lend and noting shadow prices on working capital for each amount. When the shadow price on working capital falls to 15¢ (or some other arbitrary limit), the farmer's level of income, composition of crops produced and employment levels could be noted and contrasted against the level of these same variables when the shadow price falls to zero. One could also note the level of total income the farmer earns with each increment in working capital as an estimate of the amount of working capital needed to earn a given level of total income.

A third area to be explored is the importance of labor sales versus cropping activities. In the present analysis, local labor sales were virtually unlimited throughout Categories 1, 2, 3, and 4. Migratory labor sales were allowed in quite ample amounts and farmers migrated for a total of 120 days in every solution. This is not very realistic, because most farmers do not migrate 120 days, some do not migrate at all, and very few actually have the option of selling all their labor locally. A more realistic limit for local labor sales might be 25% of the family's total labor supply. This would allow the farmer to sell some labor to larger landowners who need assistance with cropping tasks and would also provide a means of accounting for any other economic activities the farmer or the family engage in (such as marketing or firewood gathering) which are essentially alternate forms of local employment.

The effect of constraining the level of local labor sales was considered briefly in Solutions 55-63 of Appendix A, but it would be worthwhile to broaden this analysis to get a better idea of how the small farmer's position would be altered if he were constrained from selling migratory labor and allowed to sell only a limited amount of local labor.

A fourth extension would be to include demand constraints in the typical small farm model. A typical small farm model is not, of course, an appropriate framework for analyzing demand constraints. Ideally, a national LP model would be constructed for this type of analysis. The national model would include farms of all sizes and a large number of different crops utilizing a variety of different technologies. With such a model, one could attain a much more reliable estimate of the supply response which would result from introduction of new technologies into a given area, or on a certain size of farm. If information on price elasticities for the various crops were also included in the model, one could estimate the effects of introducing supply increasing technologies on: farm incomes; employment; total production; and on prices of individual basic grains. Unfortunately, the existing data base is not adequate for constructing a national LP model, and there are no estimates of price elasticities. Consequently, it appears as though demand constraints must either be ignored or allowed for in some artificial manner. Neither of these alternatives is desirable, but of the two, it might be less undesirable to artificially allow for demand constraints than to ignore them. This could be accomplished by calculating the percent of land devoted to corn, milpa, wheat and potatoes in the nine highland departments. These percentages could be normalized to provide estimates of the average amounts of land dedicated to each crop on the typical small farm. Production constraints might then be built into the typical farm model specifying that the amount of land devoted to each crop could not deviate from the average percentage by an arbitrary amount--perhaps 20%. In this way, the mix of crops estimated by the model would be closer to the mix of crops found on a typical small farm, and the model would avoid solutions in which only potatoes or only corn alone would be grown.

<u>Areas for additional research</u>

A considerable amount of work remains to be done in the area of data collection. One of the most important types of data needed is a semi-detailed soil survey. At present, the only available data on soil types and characteristics is a soil reconnaissance study made by Simmons, Tárano and Pinto (Simmons et al., 1958). This study identified major soil types, described their characteristics and made an approximate mapping of these soil types. This is a fine piece of work, but a semi-detailed soil map which would build upon earlier work is badly needed. At present, no one really knows how many hectares of each soil type exist in a given municipio, department, or in the entire country.

Dr. James Walker of the International Soil Testing Project has used the existing soil classification system to group similar soil types into "agricultural quality classes." If a semi-detailed soil survey and soil map were made, fairly accurate estimates of the amount of land in each soil type and, hence, in each "agricultural quality class" would become available. Such information would be valuable for future agricultural planning. Indeed, it is difficult to do any real planning without it, because at present the planner does not have a very precise estimate of the amounts and kinds of land comprising the resource base he is working from.

A second area in which basic research needs to be done is in estimating the yield response of new technologies on different types (agricultural quality classes) of soil. Ideally, technology demonstration plots on different soil types could be conducted at the same time a semi-detailed soil map was being constructed so that the two studies would become available more or less simultaneously. This information is important for two reasons. First, without knowing the expected yield that a given technological package will produce on good, average and poor soils, it is very difficult to estimate either the farm level income effect or the regional supply effect of agricultural development programs. Consequently, the policymaker is left in the uncomfortable position of either doing nothing (although he suspects something needs to be done) or of initiating a program without knowing what will be the likely effects of this program on key target variables such as total production, farm incomes, and so on. Second, if it turns out that present technologies are not capable of achieving acceptable yields on poorer quality soils, then a research program needs to be initiated to discover a technological package which will achieve higher yields, particularly for milpa, on hilly poorer lands. This is essential, because one of the most important goals of the Basic Grains Program was to increase yields to enable small farmers to maintain their subsistence standard of living on fairly small plots of land. It was hoped that introduction of more labor and capital intensive production techniques would cause employment, production and income to be increased or at least to remain constant so that rural-urban migration would be reduced. In this respect, the Basic Grains Program can be depicted as a holding action designed to temporarily alleviate certain conditions and thereby give the Government time to undertake birth control, educational and employment creation programs which are needed if the small farm population is to enter the main stream of Guatemalan economic life. If existing technologies cannot do a satisfactory job of increasing milpa production on poorer lands, the Basic Grains Program will not be successful in performing this holding action, and, consequently, additional research will be needed to find a technological package which will increase milpa production on poorer lands.

Another important area in which research is needed is the collection of information on demand for basic grains. Some estimates have been made for income elasticities of basic food groups, but there is no information on price elasticities. This information is always difficult to obtain, but it would be very useful and valuable once it was collected.

One last area in which research needs to be undertaken is the identification of areas in which employment can be increased. One of the most important conclusions of this study has been that the small one hectare farmer is essentially a marginal farmer and eventually will have to leave agriculture. Large numbers of families are in this "marginal farmer" group, and they will all need jobs. To provide these jobs, it will be necessary: (1) to identify rural (or at least non-Guatemala City) industries that are producing and which have the potential to expand; (2) to determine the major constraints impeding development of these industries; and (3) to create institutions and policies to remove existing constraints and facilitate the growth of small industry. This will not be an easy task, but it is a very important one if the small farm population is to enter the mainstream of Guatemalan economic life.

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APPENDIX A: LINEAR PROGRAMMING SOLUTIONS

Table A1. Optimal solutions under resource set 1A of Category 1[a]

Variable[b]	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Optimal solution number	1	2	3
Total income	443.47	467.69	492.07
Crop income	106.26	71.99	109.72
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	244.01	302.49	289.15
Total labor hours hired	0	0	0
Total hours used on crop activities	1173	393	570
Ha. of corn alone, V, 4			0.1314
Ha. of wheat, V, 3		0.3323	
Ha. of wheat, HV, 2	0.2617		
Ha. of milpa, V, 3			0.3686
Ha. of milpa, V, 2		0.1677	
Ha. of milpa, V, 1	0.4215		

[a]Semi-variable resources are fixed at the levels: Q50 savings; a low level of vegetable knowledge; zero ha of potato land. The semi-fixed resources are: 1 ha of crop land; nc credit; 10 hired laborers available.

[b]The letters H and V following the hectares of crops produced refer to whether the activity is carried out on hilly land, valley land, or a combination of hilly and valley land. The numbers 1, 2, 3, 4 describe the relative amount of working capital required to carry on the activity. In this table and in all subsequent tables, crop production activities are identified according to the following code: H = hilly land; V = valley land; HV = a combination of hilly and valley land; 1 = very little working capital; 2 = an intermediate amount of working capital; 3 = a high amount of working capital; 4 = a very high amount of working capital.

Table A1. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Ha. of milpa, H, 2	0.3168		
Shadow price on potato land[c]	604.44	499.38	298.96
Shadow price on vegetable knowledge[d]	57.30	49.55	38.38
Shadow price on savings[e]	0.19	0.44	0.86
Shadow price on vegetable land[c]	0	0	0
Shadow price on hilly land[c]	6.02	0	0
Shadow price on valley land[c]	11.38	41.02	47.96
Labor hours sold locally	3253	4033	3856

[c]Shadow price units in Appendix A for: potato land, vegetable land, hilly land, and valley land are Quetzales per hectare.

[d]Shadow price units in Appendix A for vegetable knowledge are Quetzales per high level of vegetable knowledge, i.e., if the farmer had enough "high level vegetable knowledge" to grow another cuerda of vegetables, his income would be increased by this amount.

[e]Shadow price units in Appendix A for savings are Quetzales per Zuetzal of savings.

Table A2. Optimal solutions under resource set 1B of Category 1[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Optimal solution number	4	5	6
Total income	447.81	480.91	524.73
Crop income	88.63	128.73	181.02
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	265.98	258.98	250.50
Total labor hours hired	0	0	0
Total hours used on crop activities	880	973	1087
Ha. of wheat, V, 3		0.5000	
Ha. of wheat, HV, 2	0.7143		
Ha. of corn alone, V, 4			0.5000
Ha. of milpa, V, 1	0.2857		
Ha. of milpa, H, 2		0.5000	0.5000
Shadow price on potato land	721.40	488.28	801.15

[a]Semi-variable resources are fixed at the levels: Q150 savings; a low level of vegetable knowledge; zero ha of potato land. The semi-fixed resources are: 1 ha of crop land; no credit, and 10 hired laborers available.

Table A2. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Shadow price on vegetable knowledge	62.13	58.64	54.81
Shadow price on savings	0	0	0
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	30.02	16.32	16.32
Shadow price on valley land	15.29	95.19	182.83
Labor hours sold locally	3546	3453	3341

Table A3. Optimal solutions under resource set 2A of Category 1[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	7	8	9
Total income	486.17	497.14	506.10
Crop income	73.23	120.76	88.39
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	319.75	283.18	324.51
Total labor hours hired	0	0	0
Total hours used on crop activities	163	649	99
Ha. of potatoes, V, 4			0.0691
Ha. of potatoes, HV, 3		0.0170	
Ha. of potatoes, HV, 2	0.1133		
Ha. of milpa, V, 3		0.4905	
Shadow price on potato land	0	0	0

[a]Semi-variable resources are fixed at the levels: Q50 savings; a low level of vegetable knowledge, and one hectare of potato land. Semi-fixed variables are: 1 ha of crop land; no credit; 10 hired laborers available.

Table A3. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on vegetable knowledge	31.07	27.14	20.71
Shadow price on savings	1.22	1.36	1.62
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	0	0	0
Shadow price on valley land	0	8.21	0
Labor hours sold locally	4263	3777	4326

Table A4. Optimal solutions under resource set 2B of Category 1[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	10	11	12
Total income	608.22	632.92	668.00
Crop income	219.69	265.57	265.57
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	295.34	274.15	309.63
Total labor hours hired	0	0	0
Total hours used on crop activities	488	770	298
Ha. of potatoes, V, 4			0.2072
Ha. of potatoes, HV, 3		0.1839	
Ha. of potatoes, HV, 2	0.3400		
Ha. of milpa, V, 3		0.3970	
Shadow price on potato land	0	0	0

[a]Semi-variable resources are fixed at the levels: Q150 savings; a low level of vegetable knowledge; one hectare of potato land. Semi-fixed resources are: 1 ha of crop land; no credit; 10 hired laborers available.

Table A4. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on vegetable knowledge	31.07	27.14	20.71
Shadow price on savings	1.22	1.36	1.62
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	0	0	0
Shadow price on valley land	0	8.21	0
Labor hours sold locally	3938	3656	4128

Table A5. Optimal solutions under resource set 3A of Category 1[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	13	14	15
Total income	517.24	523.01	526.81
Crop income	119.85	148.59	127.13
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	304.19	281.22	306.48
Total labor hours hired	0	0	0
Total hours used on crop activities	370	676	340
Ha. of green onions	0.0437	0.0437	0.0437
Ha. of potatoes, V, 4			0.0332
Ha. of potatoes, HV, 2	0.0544		
Ha. of milpa, V, 3		0.3013	
Shadow price on potato land	0	0	0
Shadow price on vegetable knowledge	31.07	24.82	20.71

[a]Semi-variable resources are fixed at the levels: Q50 savings; a high level of vegetable knowledge; 1 ha of potato land. Semi-fixed resources are: 1 ha of crop land; no credit; 10 hired laborers available.

Table A5. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on savings	1.22	1.46	1.62
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	0	0	0
Shadow price on valley land	0	0	0
Labor hours sold locally	4056	3750	4086

Table A6. Optimal solutions under resource set 3B of Category 1[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	16	17	18
Total income	639.29	660.06	688.71
Crop income	266.31	308.39	303.91
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	279.78	258.47	291.60
Total labor hours hired	0	0	0
Total hours used on crop activities	695	537	538
Ha. of green onions	0.0437	0.0437	0.0437
Ha. of potatoes, V, 4			0.1713
Ha. of potatoes, HV, 3		0.1463	
Ha. of potatoes, HV, 2	0.2810		
Ha. of milpa, V, 3		0.3744	
Shadow price on potato land	0	0	0

[a]Semi-variable resources are fixed at the levels: Q150 savings; a higher level of vegetable knowledge; one hectare of potato land. Semi-fixed resources are: 1 ha of crop land, no credit; 10 hired laborers available.

Table A6. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on vegetable knowledge	31.07	27.14	0
Shadow price on savings	1.22	1.36	1.62
Shadow price on vegetable land	0	0	473.82
Shadow price on hilly land	0	0	0
Shadow price on valley land	0	8.21	0
Labor hours sold locally	3731	3446	3888

Table A7. Optimal solutions under resource set 4, Category 2[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Optimal solution number	19	20	21
Total income	446.68	478.99	521.96
Crop income	87.50	126.82	178.26
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	265.98	258.98	250.50
Total labor hours hired	0	0	0
Total hours used on crop activities	880	973	1087
Ha. of wheat, V, 3		0.500	
Ha. of wheat, HV, 2	0.7143		
Ha. of corn alone, V, 4			0.500
Ha. of milpa, V, 1	0.2857		
Ha. of milpa, H, 2		0.500	0.500

[a]Semi-variable resources are fixed at the levels: zero hectares of potato land and a low level of vegetable knowledge. Semi-fixed resources are: 1 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A7. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Shadow price on potato land	667.19	704.55	742.36
Shadow price on vegetable knowledge	60.88	57.61	53.85
Shadow price on savings	.05	.05	.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	23.78	13.64	13.64
Shadow price on valley land	14.28	89.04	174.98
Labor hours sold locally	3546	3453	3341
Total amount of borrowed capital	22.56	38.27	55.31

Table A8. Optimal solutions under resource set 5, Category 2[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	22	23	24
Total income	891.61	1098.63	1120.72
Crop income	565.90	777.59	802.76
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	232.52	227.86	224.76
Total labor hours hired	0	0	0
Total hours used on crop activities	1326	1387	1430
Ha. of potatoes, V, 4			0.1755
Ha. of potatoes, HV, 3		0.7768	0.5794
Ha. of potatoes, HV, 2	0.8772		
Ha. of wheat, V, 3	0.1228		
Ha. of corn alone, V, 4		0.0650	
Ha. of milpa, H, 2		0.1582	0.2451
Shadow price on potato land	0	0	0

[a]Semi-variable resources are fixed at the levels 1 ha of potato land and a low level of vegetable knowledge. Semi-fixed resources are: 1 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A8. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on vegetable knowledge	60.89	53.85	39.00
Shadow price on savings	0.05	1.20	0.91
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	764.11	13.64	13.64
Shadow price on valley land	14.28	174.98	514.98
Labor hours sold locally	3100	3039	2996
Total amount of borrowed capital	352.14	468.68	463.12

Table A9. Optimal solutions under resource set 6, Category 2[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	25	26	27
Total income	949.22	1145.16	1154.27
Crop income	643.64	843.20	853.60
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	212.38	208.75	207.47
Total labor hours hired	0	0	0
Total hours used on crop activities	1595	1642	1659
Ha. of green onions	0.0437	0.0437	0.0437
Ha. of potatoes, V, 4			0.0724
Ha. of potatoes, HV, 3		0.7669	0.6855
Ha. of potatoes, HV, 2	0.8772		
Ha. of wheat, V, 3	0.0791		
Ha. of corn alone, V, 4		0.0268	
Ha. of milpa, H, 2		0.1626	0.1984

[a]Semi-variable resources are fixed at the levels 1 ha of potato land and a high level of vegetable knowledge. Semi-fixed resources are: 1 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A9. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on potato land	0	0	0
Shadow price on vegetable knowledge	57.61	23.87	16.70
Shadow price on savings	0.05	1.20	0.91
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	838.88	13.64	13.64
Shadow price on valley land	89.04	174.98	514.98
Labor hours sold locally	2831	2784	2767
Total amount of borrowed capital	372.77	482.57	480.27

Table A10. Optimal solutions under resource set 7, Category 3[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Optimal solution number	28	29	30
Total income	482.12	573.37	698.09
Crop income	216.92	302.82	420.59
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	172.00	177.35	184.30
Highest shadow price and quarter it occurs for labor hours hired	0.023 4th Qr.	0.026 4th Qr.	0.026 4th Qr.
Total hours used on crop activities	2132	2062	1968
Ha. of wheat, V, 3		1.5000	
Ha. of wheat, HV, 2	2.1429		
Ha. of corn alone, V, 4			1.5000
Ha. of corn alone, V, 2	0.8549		
Ha. of milpa, V, 1	0.0022		
Ha. of milpa, H, 2		0.8909	0.5843

[a]Semi-variable resources are fixed at the levels zero hectares of potato land, and a low level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 0 hired laborers available.

Table A10. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Shadow price on potato land	674.36	717.67	754.26
Shadow price on vegetable knowledge	61.34	57.95	54.31
Shadow price on savings	0.05	0.05	0.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	18.39	0	0
Shadow price on valley land	3.70	81.30	164.45
Labor hours sold locally	2294	2364	2458
Total amount of borrowed capital	185.09	182.19	216.89

Table A11. Optimal solutions under resource set 8, Category 3[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	31	32	33
Total income	1052.07	1452.34	1669.11
Crop income	876.00	1296.10	1522.04
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	82.87	63.04	53.88
Highest shadow price and quarter it occurs for labor hours hired	0 All quarters	0.026 4th Qr.	0.036 2nd Qr.
Total hours used on crop activities	3322	3586	3707
Ha. of potatoes, V, 4			1.0000
Ha. of potatoes, HV, 3		1.0000	
Ha. of potatoes, HV, 2	1.0000		
Ha. of wheat, V, 3	1.0700		
Ha. of corn alone, V, 4		0.9400	0.5000
Ha. of milpa, H, 2	0.9300	1.0166	1.3420

[a]Semi-variable resources are fixed at the levels 1 hectare of potato land and a low level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit, Q50 savings; 0 hired laborers available.

Table A11. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on potato land	470.39	754.26	942.25
Shadow price on vegetable knowledge	57.61	54.31	47.82
Shadow price on savings	0.05	0.05	0.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	13.64	0	0
Shadow price on valley land	89.04	164.45	166.32
Labor hours sold locally	1104	840	719
Total amount of borrowed capital	572.63	795.74	824.22

Table A12. Optimal solutions under resource set 9, Category 3[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	34	35	36
Total income	1107.06	1500.80	1716.93
Crop income	930.91	1322.15	1542.57
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	82.96	85.44	81.17
Highest shadow price and quarter it occurs for labor hours hired	0.036 2nd Qr.	0.036 2nd Qr.	0.036 2nd Qr.
Total hours used on crop activities	3321	3287	3344
Ha. of green onions	0.0437	0.0437	0.0437
Ha. of potatoes, V, 4			1.0000
Ha. of potatoes, HV, 3		1.0000	
Ha. of potatoes, HV, 2	1.0000		
Ha. of wheat, V, 3	1.0263		
Ha. of corn alone, V, 4		0.8963	0.4563
Ha. of milpa, H, 2	0.7384	0.6208	0.9000

[a]Semi-variable resources are fixed at the levels 1 hectare of potato land and a high level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 0 hired laborers available.

Table A12. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on potato land	453.64	726.11	942.25
Shadow price on vegetable knowledge	51.46	47.82	47.82
Shadow price on savings	0.05	0.05	0.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	0	0	0
Shadow price on valley land	83.05	166.32	166.32
Labor hours sold locally	1105	1139	1082
Total amount of borrowed capital	582.99	793.68	819.68

Table A13. Optimal solutions under resource set 10, Category 3[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	37	38	39
Total income	1375.55	1981.04	2291.51
Crop income	1148.08	1753.56	2064.04
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	134.28	134.28	134.28
Highest shadow price and quarter it occurs for labor hours hired	0.713 2nd Qr.	1.17 2nd Qr.	0.66 2nd Qr.
Total hours used on crop activities	2636	2636	2636
Ha. of potatoes, V, 4			1.0731
Ha. of potatoes, HV, 3		1.8354	0.7623
Ha. of potatoes, HV, 2	1.8354		
Shadow price on potato land	0	0	0
Shadow price on vegetable knowledge	0	0	0

[a]Semi-variable resources are fixed at the levels 3 hectares of potato land and a high level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 0 hired laborers available.

Table A13. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on savings	0.05	0.05	0.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	0	0	0
Shadow price on valley land	0	0	657.54
Labor hours sold locally	1790	1790	1790
Total amount of borrowed capital	759.84	1131.38	1217.39

Table A14. Optimal solutions under resource set 11, Category 4[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Optimal solution number	40	41	42
Total income	484.63	581.38	703.76
Crop income	249.31	352.12	455.52
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	142.13	136.05	155.04
Total labor hours hired	108, 4th Qr.	307, 4th Qr.	217, 4th Qr.
Total hours used on crop activities	2531	2612	2358
Ha. of wheat, V, 3		1.5000	
Ha. of wheat, HV, 2	2.1429		
Ha. of corn alone, V, 4			1.5000
Ha. of milpa, V, 1	0.8571		
Ha. of milpa, H, 2		1.5000	1.0159
Shadow price on potato land	667.48	705.03	770.16

[a]Semi-variable resources are fixed at the levels zero hectares of potato land and a low level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A14. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL2
Shadow price on vegetable knowledge	60.90	57.62	55.55
Shadow price on savings	0.05	0.05	0.30
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	23.56	13.14	0
Shadow price on valley land	13.84	88.76	136.06
Labor hours sold locally	1895	1814	2068
Total amount of borrowed capital	167.67	214.81	240.00

Table A15. Optimal solutions under resource set 12, Category 4[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	43	44	45
Total income	1052.07	1453.91	1671.14
Crop income	876.00	1299.62	1530.99
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	82.87	60.09	46.95
Total labor hours hired	0	22, 4th Qr.	73, 4th Qr. & 58, 2nd Qr.
Total hours used on crop activities	3322	3625	3800
Ha. of potatoes, V, 4			1.0000
Ha. of potatoes, HV, 3		1.0000	
Ha. of potatoes, HV, 2	1.0000		
Ha. of wheat, V, 3	1.0700		
Ha. of corn alone, V, 4		0.9400	0.5000
Ha. of milpa, H, 2	0.9300	1.0600	1.5000

[a]Semi-variable resources are fixed at the levels one hectare of potato land and a low level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A15. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on potato land	470.39	742.80	960.59
Shadow price on vegetable knowledge	57.61	53.87	53.71
Shadow price on savings	0.05	0.05	0.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	13.64	13.14	12.78
Shadow price on valley land	89.04	174.59	174.36
Labor hours sold locally	1104	801	626
Total amount of borrowed capital	572.63	798.07	832.68

Table A16. Optimal solutions under resource set 13, Category 4[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	46	47	48
Total income	1109.61	1506.63	1724.85
Crop income	948.45	1362.01	1593.30
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	67.96	51.41	38.35
Total labor hours hired	70, 2nd Qr.	160, 2nd Qr. 5, 4th Qr.	218, 2nd Qr. 56, 4th Qr.
Total hours used on crop activities	3520	3741	3915
Ha. of green onions	0.0437	0.0437	0.0437
Ha. of potatoes, V, 4			1.0000
Ha. of potatoes, HV, 3		1.0000	
Ha. of potatoes, HV, 2	1.0000		
Ha. of wheat, V, 3	1.0263		
Ha. of corn alone, V, 4		0.8963	0.4563
Ha. of milpa, H, 2	0.9300	1.0600	1.5000

[a]Semi-variable resources are fixed at the levels one hectare of potato land and a high level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A16. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on potato land	469.94	742.36	960.59
Shadow price on vegetable knowledge	57.44	53.71	53.71
Shadow price on savings	0.05	0.05	0.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	13.28	12.78	12.78
Shadow price on valley land	88.88	174.36	174.36
Labor hours sold locally	906	685	511
Total amount of borrowed capital	593.25	817.21	851.82

Table A17. Optimal solutions under resource set 14, Category 4[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	49	50	51
Total income	1818.62	2324.63	2420.50
Crop income	1623.14	2160.31	2270.15
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	102.30	71.11	57.15
Total labor hours hired	635, 2nd Qr. 281, 1st Qr.	508, 2nd Qr. 117, 1st Qr.	512, 2nd Qr. 106, 1st Qr.
Total hours used on crop activities	3062	3478	3664
Ha. of potatoes, V, 4			0.7615
Ha. of potatoes, HV, 3		2.1751	1.3187
Ha. of potatoes, HV, 2	2.6316		
Ha. of wheat, V, 3	0.3684		
Ha. of corn alone, V, 4		0.2820	
Ha. of milpa, H, 2		0.5429	0.9198
Shadow price on potato land	0	0	0

[a]Semi-variable resources are fixed at the levels three hectares of potato land and a low level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A17. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on vegetable knowledge	62.65	56.27	41.42
Shadow price on savings	0.05	1.20	0.91
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	776.79	13.07	13.07
Shadow price on valley land	28.83	174.63	514.66
Labor hours sold locally	1364	948	762
Total amount of borrowed capital	1156.44	1423.37	1399.26

Table A18. Optimal solutions under resource set 15, Category 4[a]

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Optimal solution number	52	53	54
Total income	1876.05	2378.30	2459.32
Crop income	1686.98	2219.95	2312.77
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	95.89	65.14	53.34
Total labor hours hired	799, 2nd Qr. 300, 1st Qr.	669, 2nd Qr. 135, 1st Qr.	672, 2nd Qr. 126, 1st Qr.
Total hours used on crop activities	3148	3557	3715
Ha. of green onions	0.0437	0.0437	0.0437
Ha. of potatoes, V, 4			0.6435
Ha. of potatoes, HV, 3		2.1750	1.4514
Ha. of potatoes, HV, 2	2.6316		
Ha. of wheat, V, 3	0.3247		
Ha. of corn alone, V, 4		0.2383	
Ha. of milpa, H, 2		0.5430	0.8614

[a]Semi-variable resources are fixed at the levels 3 hectares of potato land and a high level of vegetable knowledge. Semi-fixed resources are: 3 ha of crop land; Government credit; Q50 savings; 10 hired laborers available.

Table A18. (continued)

Variable	Crop knowledge level TL1	Crop knowledge level TL2	Crop knowledge level TL3
Shadow price on potato land	0	0	0
Shadow price on vegetable knowledge	57.43	53.67	38.82
Shadow price on savings	0.05	1.20	0.91
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	836.75	13.07	13.07
Shadow price on valley land	88.79	174.63	514.66
Labor hours sold locally	1278	869	711
Total amount of borrowed capital	1177.06	1442.50	1422.13

Table A19. Optimal solutions under resource set 16[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1	Crop knowledge level TL1
Optimal solution number	55	56	57
Total income	314.72	335.03	339.35
Crop income	115.66	136.79	141.12
Migratory labor sale income	93.20	93.20	93.20
Local labor sale income	105.87	105.04	105.04
Total labor hours hired	0	0	0
Total hours used on crop activities	1444	1344	1344
Ha. of late beets	0.0254		
Ha. of milpa, V, 2		0.5000	0.5000
Ha. of milpa, V, 1	0.4746		
Ha. of milpa, H, 2	0.5000	0.3692	0.5000
Ha. of milpa, H, 1		0.1308	
Shadow price on potato land	771.67	189.58	770.27
Shadow price on vegetable knowledge	81.82	52.46	77.92

[a]Resource levels are held constant at: 1 ha of crop land; 0 ha of potato land; 10 hired laborers available; a low level of vegetable knowledge; and Q50 savings. The amount of local labor sales is restricted in these solutions.

Table A19. (continued)

Variable	Crop knowledge level TLO	Crop knowledge level TL1	Crop knowledge level TL1
Shadow price on savings	0.002	1.13	0.05
Shadow price on vegetable land	0	0	0
Shadow price on hilly land	84.00	23.71	81.44
Shadow price on valley land	78.32	66.65	125.36
Labor hours sold locally	353	350	350
Total amount of borrowed capital	0.00	No credit	4.02

Table A20. Optimal solutions under resource set 16[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1
Optimal solution number	58	59
Total income	445.65	504.66
Crop income	290.23	363.36
Migratory labor sale income	93.20	93.20
Local labor sale income	62.22	48.10
Total labor hours hired	376	436
Total hours used on crop activities	3142	3273
Ha. of wheat, HV, 2	0.7852	
Ha. of milpa, V, 2		1.5000
Ha. of milpa, V, 1	1.2645	
Ha. of milpa, H, 2	0.9503	1.2751
Shadow price on potato land	1266.81	1867.46
Shadow price on vegetable knowledge	74.57	47.50
Shadow price on savings	0.012	0.58

[a]Resource levels are held constant at: 3 ha of crop land; 0 ha of potato land; 10 hired laborers available; a low level of vegetable knowledge; Q150 savings; and no access to credit. Local labor sales are restricted in these solutions.

Table A20. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1
Shadow price on vegetable land	0	0
Shadow price on hilly land	57.63	0
Shadow price on valley land	53.20	43.82
Labor hours sold locally	830	641

Table A21. Optimal solutions under resource set 16[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1
Optimal solution number	60	61
Total income	441.10	523.18
Crop income	292.55	355.58
Migratory labor sale income	93.20	93.20
Local labor sale income	55.35	74.40
Total labor hours hired	430	337
Total hours used on crop activities	3325	3071
Ha. of wheat, V, 3		1.3000
Ha. of wheat, HV, 2	.5085	
Ha. of milpa, V, 2		.2000
Ha. of milpa, V, 1	1.3475	
Ha. of milpa, H, 2	1.1440	1.5000
Shadow price on potato land	104.30	131.04
Shadow price on vegetable knowledge	72.54	73.49

[a]Resource levels are held constant at: 3 ha of crop land; 0 ha of potato land; 10 hired laborers available; low level of vegetable knowledge; Q50 savings; and Government credit. The amount of local labor sales is restricted in these solutions. Potato price of Q2.75/qq. was used in this solution. This is why the shadow price on potato land is lower than usual.

Table A21. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1
Shadow price on savings	0.05	0.05
Shadow price on vegetable land	0	0
Shadow price on hilly land	53.03	63.19
Shadow price on valley land	49.64	107.66
Labor hours sold locally	738	992
Total amount of borrowed capital	86.22	201.10

Table A22. Optimal solutions under resource set 16[a]

Variable	Crop knowledge level TL0	Crop knowledge level TL1
Optimal solution number	62	63
Total income	479.73	552.76
Crop income	290.23	215.98
Migratory labor sale income	93.20	93.20
Local labor sale income	96.29	243.58
Total labor hours hired	376	0
Total hours used on crop activities	3142	1179
Ha. of wheat, V, 3		0.9969
Ha. of wheat, HV, 2	0.7852	
Ha. of milpa, V, 2		0.5031
Ha. of milpa, V, 1	1.2644	
Ha. of milpa, H, 2	0.9504	
Shadow price on potato land	602.99	499.38
Shadow price on vegetable knowledge	57.22	49.55

[a]Resource levels are constant at: 3 ha of cropland; 10 hired laborers available; 0 ha of potato land; a low level of vegetable knowledge; no credit; and Q150 savings. Local labor sales are not restricted in this solution.

Table A22. (continued)

Variable	Crop knowledge level TL0	Crop knowledge level TL1
Shadow price on savings	0.196	0.441
Shadow price on vegetable land	0	0
Shadow price on hilly land	5.30	0
Shadow price on valley land	10.86	41.02
Labor hours sold locally	1284	3247
Total amount of borrowed capital	No credit	No credit

APPENDIX B: THE LINEAR PROGRAMMING MODEL

Table B-1. Identification number, type, name, unit, RHS value and description of the rows

Identification number	Row type[a]	Row name[b]	Unit[c]	RHS value[d]	Row description
1	N	INCOME	1 Quetzal	-[e]	Objective function to be maximized
2	L	CHT1*	1 hour		1st quarter hours available for crop activities
3	L	CHT2*			2nd quarter hours available for crop activities
4	L	CHT3*			3rd quarter hours available for crop activities
5	L	CHT4*			4th quarter hours available for crop activities

[a]Row types are N, L, E, G. N identifies the function to be optimized. L means maximum restraint (less than or equal to). E means equality restraint. G means minimum restraint (greater than or equal to).

[b]Starred row names belong to transfer rows. The numbers 1, 2, 3, 4 refer to quarters of the year.

[c]Blank means that the unit in the previous row applies. For example, 1 hour is the unit for rows 2 through 17.

[d]RHS values are the right-hand-side values in the equations that make up the matrix. All transfer rows have a zero (blank) value. A star indicates that the value given here was subject to parametric variation. All RHS values given here are for Solution 54. RHS values for other solutions are given in Chapters V and VI.

[e]Does not apply.

Table B-1. (continued)

Identification number	Row type	Row name	Unit	RHS value	Row description
6	L	THA1*			Total hours available in 1st quarter
7	L	THA2*			Total hours available in 2nd quarter
8	L	THA3*			Total hours available in 3rd quarter
9	L	THA4*			Total hours available in 4th quarter
10	L	FTA1		632	Farmer time available in 1st quarter
11	L	FTA2		632	Farmer time available in 2nd quarter
12	L	FTA3		624	Farmer time available in 3rd quarter
13	L	FTA4		616	Farmer time available in 4th quarter
14	L	FEA1		695	Family "farmer equivalent" time, 1st quarter
15	L	FEA2		695	Family "farmer equivalent" time, 2nd quarter

Table B-1. (continued)

Identification number	Row type	Row name	Unit	RHS value	Row description
16	L	FEA3		686	Family "farmer equivalent" time, 3rd quarter
17	L	FEA4		678	Family "farmer equivalent" time, 4th quarter
18	L	MD3	208 hours	416	Migratory demand for farmer time, 3rd quarter
19	L	MD4		416	Migratory demand for farmer time, 4th quarter
20	L	LD1	1 hour	1327	Local demand for farmer and family labor, 1st quarter
21	L	LD2		1327	Local demand for farmer and family labor, 2nd quarter
22	L	LD3		1310	Local demand for farmer and family labor, 3rd quarter
23	L	LD4		1294	Local demand for farmer and family labor, 4th quarter
24	L	FL	1 hectare	1.5*	Flat or valley land
25	L	ML		1.5*	Mountainside or hilly land

Table B-1. (continued)

Identification number	Row type	Row name	Unit	RHS value	Row description
26	L	VL		0.0437*	Vegetable land
27	L	CNT*	1 quintal		Corn transfer row
28	L	BNT*			Bean transfer row
29	L	HT*			Haba transfer row
30	L	GAT*	1 squash		Guicoy or Ayote transfer row
31	L	CHT*	1 gourd		Chilacayote transfer row
32	L	PT*	1 quintal		Potato transfer row
33	L	WT*			Wheat transfer row
34	L	EBT*	1 dozen		Early beet transfer row
35	L	LBT*			Later beet transfer row
36	L	GOT*	1000 onions		Green onion transfer row
37	L	ECT*	1 dozen		Early carrot transfer row
38	L	LCT*			Later carrot transfer row
39	L	MLCM	1 Quetzal	240*	Maximum loan for corn and milpa production

Table B-1. (continued)

Identification number	Row type	Row name	Unit	RHS value	Row description
40	L	MLW		330*	Maximum loan for wheat production
41	L	MLP		1350*	Maximum loan for potato production
42	L	MLV		19.65*	Maximum loan for vegetable production
43	L	MLH1	1 hour	6320*	Maximum hours hired labor available, 1st quarter
44	L	MLH2		6320*	Maximum hours hired labor available, 2nd quarter
45	L	MLH3		6240*	Maximum hours hired labor available, 3rd quarter
46	L	MLH4		6160*	Maximum hours hired labor available, 4th quarter
47	L	TKCM*	1 Quetzal		Transfer row providing working capital for corn and milpa
48	L	TKW*			Transfer row providing working capital for wheat
49	L	TKP*			Transfer row providing working capital for potatoes

Table B-1. (continued)

Identification number	Row type	Row name	Unit	RHS value	Row description
50	L	TKV*			Transfer row providing working capital for vegetables
51	L	TS		50*	Total savings available
52	L	CYLL		0	Accounting row for local labor sales income
53	L	CYML		0	Accounting row for migratory labor sales income
54	L	CYC		0	Accounting row for crop sales income
55	L	TL1	Level 1	3*	Crop knowledge level TL1
56	L	TL2	Level 2	3*	Crop knowledge level TL2
57	L	TL3	Level 3	3*	Crop knowledge level TL3
58	L	TLV	Level V	1*	Vegetable knowledge level 1 (high)
59	L	PTOL	1 hectare	3*	Potato land available

Table B-2. Identification number, name, unit, objective function coefficient and description of columns

Identification number[a]	Column name[b]	Unit[c]	Objective function coefficient[d]	Column description
60	MH1	1 hectare	-22.87	Milpa grown on hilly land requiring very little working capital (corresponding description applies to Columns 61 through 75)[e]
61	MH2		-53.56	
62	MV1		-20.35	
63	MV2		-54.47	
64	MV3		-79.66	
65	CV2		-40.73	

[a]Continuation of identification numbers in B-1.

[b]Starred column names belong to transfer activities.

[c]A blank means that the unit in the previous row applies.

[d]Negative values are net cost of the activity; positive figures are revenue from the activity; a zero (blank) value indicates that the cost-revenue of the activity is accounted for somewhere else in the model or that the column is only an accounting activity.

[e]According to the following code: M = milpa; C = corn alone; W = wheat; P = potatoes, H = hilly land; V = valley land; HV = a combination of hilly and valley land; 1 = very little working capital; 2 = an intermediate amount of working capital; 3 = a high amount of working capital; 4 = a very high amount of working capital.

Table B-2. (continued)

Identification number	Column name	Unit	Objective function coefficient	Column description
66	CV3		-77.82	
67	CV4		-157.04	
68	WHV1		-78.33	
69	WHV2		-93.44	
70	WV3		-122.98	
71	WV4		-203.59	
72	PHV1		-206.06	
73	PHV2		-441.23	
74	PHV3		-643.66	
75	PV4		-723.81	
76	EB	.0437 hectares	-23.29	Early beets
77	LB		-23.29	Later beets
78	GO		-26.00	Green onions
79	ECR		-16.43	Early carrots

Table B-2. (continued)

Identification number	Column name	Unit	Objective function coefficient	Column description
80	LCR		- 16.43	Later carrots
81	SCN	1 cwt	3.30	Sell corn
82	SBN		10.00	Sell beans
83	SH		10.00	Sell habas
84	SGA	1 squash	0.07	Sell guicoy and/or ayote squash
85	SCH	1 gourd	0.10	Sell chilacayote gourd
86	SP	1 cwt	4.75	Sell potatoes
87	SW		5.75	Sell wheat
88	SEB	1 doz.	0.065	Sell early beets
89	SLB		0.070	Sell later beets
90	SGO	1000	7.00	Sell green onions
91	SEC	1 doz.	0.088	Sell early carrots
92	SLC		0.088	Sell later carrots
93	CH1*	1 hour		Transfer column for total hours available in 1st quarter

Table B-2. (continued)

Identification number	Column name	Unit	Objective function coefficient	Column description
94	CH2*			Transfer column for total hours available in 2nd quarter
95	CH3*			Transfer column for total hours available in 3rd quarter
96	CH4*			Transfer column for total hours available in 4th quarter
97	UFT1			Use farmer time in 1st quarter
98	UFT2			Use farmer time in 2nd quarter
99	UFT3			Use farmer time in 3rd quarter
100	UFT4			Use farmer time in 4th quarter
101	UFE1			Use family "farmer equivalent" time in 1st quarter
102	UFE2			Use family "farmer equivalent" time in 2nd quarter
103	UFE3			Use family "farmer equivalent" time in 3rd quarter
104	UFE4			Use family "farmer equivalent" time in 4th quarter

Table B-2. (continued)

Identification number	Column name	Unit	Objective function coefficient	Column description
105	HH1		- 0.076	Hire labor 1st quarter
106	HH2		- 0.076	Hire labor 2nd quarter
107	HH3		- 0.076	Hire labor 3rd quarter
108	HH4		- 0.076	Hire labor 4th quarter
109	SMF3		23.30	Sell migratory labor 3rd quarter
110	SMF4		23.30	Sell migratory labor 4th quarter
111	SFT1		0.075	Sell farmer labor locally in 1st quarter
112	SFT2		0.075	Sell farmer labor locally in 2nd quarter
113	SFT3		0.075	Sell farmer labor locally in 3rd quarter
114	SFT4		0.075	Sell farmer labor locally in 4th quarter
115	SFE1		0.075	Sell family labor locally in 1st quarter

Table B-2. (continued)

Identification number	Column name	Unit	Objective function coefficient	Column description
116	SFE2		0.075	Sell family labor locally in 2nd quarter
117	SFE3		0.075	Sell family labor locally in 3rd quarter
118	SFE4		0.075	Sell family labor locally in 4th quarter
119	BKCM	1 Quetzal	-0.10	Borrow working capital for corn and milpa activities
120	BKW		-0.10	Borrow working capital for wheat activities
121	BKP		-0.10	Borrow working capital for potato activities
122	BKV		-0.10	Borrow working capital for vegetables activities
123	ASCM		-0.05	Allocate savings to corn and milpa activities
124	ASW		-0.05	Allocate savings to wheat activities
125	ASP		-0.05	Allocate savings to potatoes activities

Table B-2. (continued)

Identification number	Column name	Unit	Objective function coefficient	Column description
126	ASV		-0.05	Allocate savings to vegetables activities
127	AYLL			Accounting activity for local labor income
128	AYML			Accounting activity for migratory labor income
129	AYC			Accounting activity for crop income

Table B-3. Linear programming matrix[a]

Name	Model 5

Rows

N	C
L	CHT1
L	CHT2
L	CHT3
L	CHT4
L	THA1
L	THA2
L	THA3
L	THA4
L	FTA1
L	FTA2
L	FTA3
L	FTA4
L	FEA1
L	FEA2
L	FEA3
L	FEA4
L	MD3
L	MD4
L	LD1
L	LD2
L	LD3
L	LD4
L	FL
L	ML
L	VL
L	CNT
L	BNT
L	HT
L	GAT
L	CHT
L	PT
L	WT
L	EBT
L	LBT

[a]In the RHS section of the matrix only the vector for Solution 54 is reproduced. The RHS values for the other solutions are discussed and explained in Chapters V and VI.

Table B-3. (continued)

Name		Model 5
L	GOT	
L	ECT	
L	LCT	
L	MLCM	
L	MLW	
L	MLP	
L	MLV	
L	MLH1	
L	MLH2	
L	MLH3	
L	MLH4	
L	TKCM	
L	TKW	
L	TKP	
L	TKV	
L	TS	
L	CYLL	
L	CYML	
L	CYC	
L	TL1	
L	TL2	
L	TL3	
L	TLV	
L	PTOL	

Columns

MH1	C	- 22.87000	CHT1		206.00000
MH1	CHT2	364.00000	CHT3		334.00000
MH1	CHT4	504.00000	ML		1.00000
MH1	CNT	- 20.04000	BNT	-	1.43000
MH1	HT	- 1.43000	GAT	-	137.00000
MH1	CHT	- 70.00000	TKCM		22.87000
MH1	CYC	88.45000			
MH2	C	- 53.56000	CHT1		206.00000
MH2	CHT2	364.00000	CHT3		334.00000
MH2	CHT4	504.00000	ML		1.00000
MH2	CNT	- 22.90000	BNT	-	4.30000
MH2	HT	- 4.30000	GAT	-	137.00000
MH2	CHT	- 70.00000	TKCM		53.56000
MH2	CYC	124.60000			
MV1	C	- 20.35000	CHT1		147.00000
MV1	CHT2	369.00000	CHT3		325.00000

Table B-3. (continued)

Name	Model 5					
MV1	CHT4		435.00000	FL		1.00000
MV1	CNT	-	22.90000	BNT	-	2.01000
MV1	HT	-	2.01000	GAT	-	137.00000
MV1	CHT	-	70.00000	TKCM		20.35000
MV1	CYC		112.01000			
MV2	C	-	54.47000	CHT1		147.00000
MV2	CHT2		369.00000	CHT3		325.00000
MV2	CHT4		435.00000	FL		1.00000
MV2	CNT	-	50.52000	BNT	-	1.73000
MV2	HT	-	1.73000	GAT	-	137.00000
MV2	CHT	-	70.00000	TKCM		54.47000
MV2	CYC		163.44000	TL1		1.00000
MV3	C	-	79.66000	CHT1		147.00000
MV3	CHT2		369.00000	CHT3		325.00000
MV3	CHT4		435.00000	FL		1.00000
MV3	CNT	-	60.46000	BNT	-	3.98000
MV3	HT	-	3.98000	GAT	-	137.00000
MV3	CHT	-	70.00000	TKCM		79.66000
MV3	CYC		216.05000	TL2		1.00000
CV2	C	-	40.73000	CHT1		112.00000
CV2	CHT2		231.00000	CHT3		32.00000
CV2	CHT4		309.00000	FL		1.00000
CV2	CNT	-	32.52000	TKCM		40.73000
CV2	CYC		66.59000			
CV3	C	-	77.82000	CHT1		112.00000
CV3	CHT2		231.00000	CHT3		32.00000
CV3	CHT4		389.00000	FL		1.00000
CV3	CNT	-	50.38000	TKCM		77.82000
CV3	CYC		88.43000	TL1		1.00000
CV4	C	-	157.06000	CHT1		112.00000
CV4	CHT2		231.00000	CHT3		32.00000
CV4	CHT4		389.00000	FL		1.00000
CV4	CNT	-	122.74000	TKCM		157.06000
CV4	CYC		247.98000	TL2		1.00000
WHV1	C	-	78.33000	CHT1		275.00000
WHV1	CHT2		387.00000	CHT4		344.00000
WHV1	FL		.46000	ML		.54000
WHV1	WT	-	28.17000	TKW		78.33000
WHV1	CYC		83.65000			
WHV2	C	-	93.44000	CHT1		275.00000
WHV2	CHT2		160.00000	CHT4		286.00000
WHV2	FL		.30000	ML		.70000
WHV2	WT	-	30.92000	TKW		93.44000
WHV2	CYC		84.35000			

Table B-3. (continued)

Name	Model 5					
WV3	C	-	122.98000	CHT1		92.00000
WV3	CHT2		160.00000	CHT4		286.00000
WV3	FL		1.00000	WT	-	46.03000
WV3	TKW		122.98000	CYC		141.69000
WV3	TL1		1.00000			
WV4	C	-	203.59000	CHT1		92.00000
WV4	CHT2		160.00000	CHT4		286.00000
WV4	FL		1.00000	WT	-	67.08000
WV4	TKW		203.59000	CYC		186.15000
WV4	TL2		1.00000			
PHV1	C	-	206.06000	CHT1		401.00000
PHV1	CHT2		458.00000	CHT3		115.00000
PHV1	FL		.50000	ML		.50000
PHV1	PT	-	45.80000	TKP		206.06000
PHV1	CYC		11.49000			
PHV2	C	-	441.23000	CHT1		598.00000
PHV2	CHT2		723.00000	CHT3		115.00000
PHV2	FL		.43000	ML		.57000
PHV2	PT	-	233.58000	TKP		441.23000
PHV2	CYC		668.28000	TL1		1.00000
PHV2	PTOL		1.00000			
PHV3	C	-	643.66000	CHT1		598.00000
PHV3	CHT2		723.00000	CHT3		115.00000
PHV3	FL		.56000	ML		.44000
PHV3	PT	-	349.91000	TKP		643.66000
PHV3	CYC		1018.41000	TL2		1.00000
PHV3	PTOL		1.00000			
PV4	C	-	723.81000	CHT1		598.00000
PV4	CHT2		723.00000	CHT3		115.00000
PV4	FL		1.00000	PT	-	429.38000
PV4	TKP		723.81000	CYC		1315.75000
PV4	TL3		1.00000	PTOL		1.00000
EB	C	-	23.29000	CHT1		7.00000
EB	CHT2		184.00000	CHT3		38.00000
EB	FL		.04370	VL		.04370
EB	EBT	-	399.00000	TKV		23.29000
EB	CYC		2.65000			
LB	C	-	23.29000	CHT2		157.00000
LB	CHT3		73.00000	FL		.04370
LB	VL		.04370	LBT	-	399.00000
LB	TKV		23.29000	CYC		4.64000
GO	C	-	26.00000	CHT1		23.00000
GO	CHT2		171.00000	CHT3		98.00000

Table B-3. (continued)

Name	Model 5			
GO	FL	.04370	VL	.04370
GO	GOT	- 16.00000	TKV	26.00000
GO	CYC	86.00000	TLV	1.00000
ECR	C	- 16.43000	CHT1	101.00000
ECR	CHT2	117.00000	CHT3	84.00000
ECR	FL	.04370	VL	.04370
ECR	ECT	- 500.00000	TKV	16.43000
ECR	CYC	27.57000	TLV	1.00000
LCR	C	- 16.43000	CHT2	201.00000
LCR	CHT3	89.00000	FL	.04370
LCR	VL	.04370	LCT	- 500.00000
LCR	TKV	16.43000	CYC	27.57000
LCR	TLV	1.00000		
SCN	C	3.30000	CNT	1.00000
SBN	C	10.00000	BNT	1.00000
SH	C	10.00000	HT	1.00000
SGA	C	.07000	GAT	1.00000
SCH	C	.10000	CHT	1.00000
SP	C	4.75000	PT	1.00000
SW	C	5.75000	WT	1.00000
SEB	C	.06500	EBT	1.00000
SLB	C	.07000	LBT	1.00000
SGO	C	7.00000	GOT	1.00000
SEC	C	.08800	ECT	1.00000
SLC	C	.08800	LCT	1.00000
CH1	CHT1	- 1.00000	THA1	1.00000
CH2	CHT2	- 1.00000	THA2	1.00000
CH3	CHT3	- 1.00000	THA3	1.00000
CH4	CHT4	- 1.00000	THA4	1.00000
UFT1	THA1	- 1.00000	FTA1	1.00000
UFT2	THA2	- 1.00000	FTA2	1.00000
UFT3	THA3	- 1.00000	FTA3	1.00000
UFT4	THA4	- 1.00000	FTA4	1.00000
UFE1	THA1	- 1.00000	FEA1	1.00000
UFE2	THA2	- 1.00000	FEA2	1.00000
UFE3	THA3	- 1.00000	FEA3	1.00000
UFE4	THA4	- 1.00000	FEA4	1.00000
HH1	C	- .07600	THA1	- 1.00000
HH1	MLH1	1.00000	CYC	- .07600
HH2	C	- .07600	THA2	- 1.00000
HH2	MLH2	1.00000	CYC	- .07600
HH3	C	- .07600	THA3	- 1.00000
HH3	MLH3	1.00000	CYC	- .07600

Table B-3. (continued)

Name	Model 5					
HH4	C	-	.07600	THA4	-	1.00000
HH4	MLH4		1.00000	CYC	-	.07600
SMF3	C		23.30000	FTA3		208.00000
SMF3	MD3		208.00000	CYML		23.30000
SMF4	C		23.30000	FTA4		208.00000
SMF4	MD4		208.00000	CYML		23.30000
SFT1	C		.07500	FTA1		1.00000
SFT1	LD1		1.00000	CYLL		.07500
SFT2	C		.07500	FTA2		1.00000
SFT2	LD2		1.00000	CYLL		.07500
SFT3	C		.07500	FTA3		1.00000
SFT3	LD3		1.00000	CYLL		.07500
SFT4	C		.07500	FTA4		1.00000
SFT4	LD4		1.00000	CYLL		.07500
SFE1	C		.07500	FEA1		1.00000
SFE1	LD1		1.00000	CYLL		.07500
SFE2	C		.07500	FEA2		1.00000
SFE2	LD2		1.00000	CYLL		.07500
SFE3	C		.07500	FEA3		1.00000
SFE3	LD3		1.00000	CYLL		.07500
SFE4	C		.07500	FEA4		1.00000
SFE4	LD4		1.00000	CYLL		.07500
BKCM	C	-	.10000	MLCM		1.00000
BKCM	TKCM	-	1.00000	CYC	-	.10000
BKW	C	-	.10000	MLW		1.00000
BKW	TKW	-	1.00000	CYC	-	.10000
BKP	C	-	.10000	MLP		1.00000
BKP	TKP	-	1.00000	CYC	-	.10000
BKV	C	-	.10000	MLV		1.00000
BKV	TKV	-	1.00000	CYC	-	.10000
ASCM	C	-	.05000	TKCM	-	1.00000
ASCM	TS		1.00000	CYC	-	.05000
ASW	C	-	.05000	TKW	-	1.00000
ASW	TS		1.00000	CYC	-	.05000
ASP	C	-	.05000	TKP	-	1.00000
ASP	TS		1.00000	CYC	-	.05000
ASV	C	-	.05000	TKV	-	1.00000
ASV	TS		1.00000	CYC	-	.05000
AYLL	CYLL	-	1.00000			
AYML	CYML	-	1.00000			
AYC	CYC	-	1.00000			

Table B-3. (continued)

Name	Model 5			
RHS				
B	FTA1	632.00000	FTA2	632.00000
B	FTA3	624.00000	FTA4	616.00000
B	FEA1	695.00000	FEA2	695.00000
B	FEA3	686.00000	FEA4	678.00000
B	MD3	416.00000	MD4	416.00000
B	LD1	1327.00000	LD2	1327.00000
B	LD3	1310.00000	LD4	1294.00000
B	FL	1.50000	ML	1.50000
B	VL	0.04370	MLH1	6320.00000
B	MLH2	6320.00000	MLH3	6240.00000
B	MLH4	6160.00000	MLCM	240.00000
B	MLW	330.00000	MLP	1350.00000
B	MLV	60.00000	TS	50.00000
B	TL1	3.00000	TL2	3.00000
B	TL3	3.00000	TLV	1.00000
B	PTOL	3.00000		

APPENDIX C: UNITS OF MEASURE

Table C-1. Units of measure used in this study, their abbreviation and equivalence

Units of measure	Abbreviation	Equivalence
Length:		
Milimeter	mm	0.03937 inches
Centimeter (=10 mm)	cm	0.3937 inches
		0.032808 feet
Meter (=100 cm)	m	39.37 inches
		3.280833 feet
		1.093611 yards
Vara	v	0.914156 yards
		0.835906 meters
Surface:		
Square meter	m^2	10.76387 square feet
Hectare (=10,000 m^2)	ha or Ha.	2.47104 acres
		1.43115 Manzanas
		22.90 cuerdas
Manzana (=10,000 v^2)	mz	1.72661 acres
		0.69874 hectares
		16.0 cuerdas
Cuerda (of 625 v^2)	cd	0.1079 acres
		0.0437 hectares
		0.0625 manzanas
Weight:		
Kilogram (=1000 grams)	kg	2.204623 pounds
Quintal (=100 lb)	qq	100.0 pounds
Metric ton (=1000 kg)	mt	2,204.623 pounds
		1000.0 kilograms
Money:		
Quetzal	Q	1.0 U.S.$

Table C-2. Equivalence between degrees Centigrade and Farenheit, from 30°C to -30°C[a]

Centigrade	Farenheit	Centigrade	Farenheit
30	86.0	-1	30.2
29	84.2	-2	28.4
28	82.4	-3	26.6
27	80.6	-4	24.8
26	78.8	-5	23.0
25	77.0	-6	21.2
24	75.2	-7	19.4
23	73.4	-8	17.6
22	71.6	-9	15.8
21	69.8	-10	14.0
20	68.0	-11	12.2
19	66.2	-12	10.4
18	64.4	-13	8.6
17	62.6	-14	6.8
16	60.8	-15	5.0
15	59.0	-16	3.2
14	57.2	-17	1.4
13	55.4	-18	-0.4
12	53.6	-19	-2.2
11	51.8	-20	-4.0
10	50.0	-21	-5.8
9	48.2	-22	-7.6
8	46.4	-23	-9.4
7	44.6	-24	-11.2
6	42.8	-25	-13.0
5	41.0	-26	-14.8
4	39.2	-27	-16.6
3	37.4	-28	-18.4
2	35.6	-29	-20.2
1	33.8	-30	-22.0
0	32.0		

[a]Formula: $F = 1.8\,C + 32$, where F is degrees Farenheit and C is degrees Centigrade.