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The use of agricultural machinery in Pichincha province, Ecuador.

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THE USE OF AGRICULTURAL MACHINERY IN PICHINCHA PROVINCE, ECUADOR

BY

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ABSTRACT

The nature of this study was to determine the degree of agricultural mechanization in an area of Pichincha Province, Ecuador. Of importance were the reasons for the present level of mechanization and the problems encountered by machinery users, or the reasons for some producers choosing not to use any agricultural machinery.

The physical and agricultural influences upon machinery use were discussed in general terms, liberally using map interpretation, secondary sources, and data collected on these aspects in the field. Field work for the study was completed in Ecuador during May to September of 1973.

The level of agricultural mechanization currently in practice was analyzed using regression analysis. This was done to explain the effects of farm size, wheat field size, distances to service centers, and wheat field slope on the present level of agricultural mechanization. It was found that wheat field slope explained fifty-nine per cent of the variations in the use of agricultural machinery; wheat field size and distances to service centers also contributed to this explanation significantly.

The problems producers experienced while using machinery on their holdings, or the reasons why some producers used no

machinery at all were analyzed, using information collected on these topics during interviews. In reference to problems, it was found that the lack of spare machinery parts and the expense of these parts were the main problems encountered. Obtaining repairs and problems arising due to irregular or steep land were also frequently cited as major problems. The main reasons for the non-use of machinery were irregularity or steepness of land, too little land, and the fact that hand labor within the study area is both abundant and cheap.

Yields were analyzed using regression analysis to explain variations caused mainly by the level of mechanization practiced, but also by fertilizer used, wheat field slope, and farm size. It was found that the level of agricultural mechanization explained thirty-six per cent of the variation in reported yields, while fertilizer used and farm size also proved to be significant in explaining variations in yields.

In conclusion, it was found that the topography and the agricultural infrastructure of the area were both significant in explaining the present level of agricultural mechanization in the study area. There is substantial use, however, of agricultural machinery within the area at present. It was found that there must be an improvement in the supplying of machinery parts and repairs at a reasonable cost to this area's agriculturalists. In general, to modernize this area's agriculture, there must be an improvement also in the provision of credit and extension services.

It is felt that through the more widespread use of agricultural machinery, where economically and physically possible, and through other modern agricultural inputs, the agricultural production of Pichincha Province could be substantially increased.

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CHAPTER I INTRODUCTION

Latin American countries are thought to have placed too little emphasis on their agricultural sectors for the good of overall national economic development; there has been a failure to recognize agriculture as an integral part of the total development process (Yudelman, 1970: 62).

One result of this lack of attention to the agricultural sectors of Latin American countries is that production has not been increasing rapidly enough to keep pace with the minimal diet requirements of growing populations; there has also been a low rural demand for farm inputs and consumer goods (Eicher, 1964: 40). This of course reflects upon the industrial sectors as a whole. The situation exists, therefore, where a great number of individuals, particularly the small agricultural producers, are not optimally participating in the national economies. Overcoming low agricultural productivity is therefore of the utmost importance to the economic development of Latin America (Comite, 1966).

This situation is acute in the agricultural sector of Ecuador, where sixty-one per cent of the country's population consists of rural inhabitants (Fletcher, 1971: 241). While a large majority of these people are tied to the agricultural sector, a great number of them contribute little or nothing to the national economy (Fletcher, 1971: 242).

It should be noted that there are two distinct segments of the agricultural sector in Ecuador. There is the agricultural activity directed toward the domestic market, and that directed toward the export market. This latter part of the agricultural sector, while including a minority of the agricultural producers, produces commodities which account for nearly ninety per cent of the country's foreign exchange earnings (Haviland, 1971: 6). Considering this fact, plus the large number of people engaged in agriculture, this sector is currently the most important segment of Ecuador's economy (Gibson, 1971).

In recent years there has been a great amount of interest shown by the Ecuadorian government in expanding and modernizing their agricultural export market. At the same time, interest in the production of domestic foodstuffs has been relatively small. Consequently, the period growth rate of export commodities was 14.9 per cent between 1950 and 1970, while the growth rate of domestic products during the same period was only 8.7 per cent (Zuvekas, 1973: 67). This has led to the use of valuable foreign exchange to import basic foodstuffs in increasing amounts (Gibson, 1971: 40).

For example, the production of wheat in Ecuador is currently averaging less than fifty per cent of the total national consumption, while demand for wheat is increasing at a rate of seven per cent annually (Yudelman, 1971: 251; Italconsult, 1963: 130). With a population growth rate of

3.2 per cent, Ecuador can little afford to neglect the production of basic food crops (Gibson, 1971: 36). In Ecuador, as elsewhere, rates of growth or decline in the total agricultural sector reflect upon the health of the total economy.

There is a need, therefore, for a concerted effort on the part of government agencies in Ecuador to develop a plan for the complete modernization of agriculture. Of equal importance is the necessity for the development of the rural service structure and auxiliary institutions within which agriculture operates. Generally, an increase is required in the use of biological and mechanical inputs in the farming system.[1] This paper will concentrate on the use of mechanical inputs, with the overall purpose of the study being to ascertain the degree of mechanization which has taken place within an area of Pichincha Province, Ecuador. While the purpose of this study is not necessarily to justify farm mechanization, a growing agricultural sector will cause the formation of economic linkages with the service and industrial sectors which in turn will contribute to national economic development.

Study Area

The area under consideration for this study is Pichincha

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1 Examples of biological inputs are fertilizers, herbicides, insecticides, and improved seed varieties, while examples of mechanical inputs are machinery, implements, and irrigation.

Province, Ecuador (Figure 1).[2] This province (16,037 Sq.Km.) is comprised of parts of two of the three natural regions of Ecuador, the Costa and the Sierra. It consists of 455,000 hectares of coastal lowlands, 729,000 hectares of Andean slopes, and 572,000 hectares of Inter-Andean terrain.[3] The main concern of this study is the Inter-Andean areas of the province. This area was chosen because temperate food crops were produced there, because it had a more widespread use of agricultural machinery, and because the area adequately exemplified the problems encountered in the use of agricultural machinery in Ecuador. Some of these problems are small farm size, steep slopes, and a general backwardness of the agricultural structure of this area. The Inter-Andean zone is composed of 233,000 hectares (49%) of possible agricultural land, 174,000 hectares (37%) of potential forest products, and 65,000 hectares (14%) hectares of no productive use (Italconsult, 1963: 28-30).

To study the mechanization of agriculture in Pichincha Province, wheat was selected as the study crop.[4] The reasons for this choice are varied: the first important consideration was the importance of wheat in terms of better dietary

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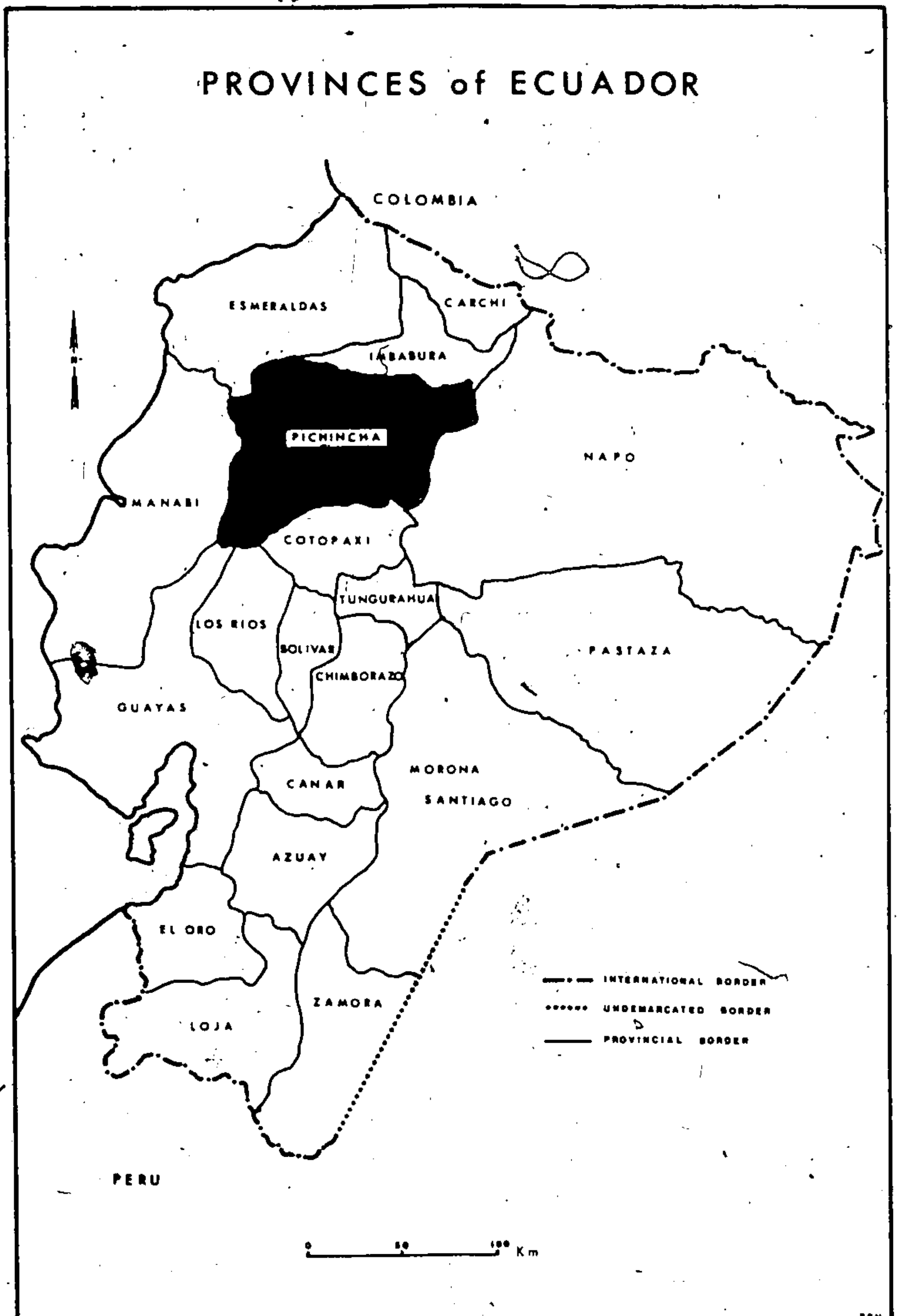
2 The author was invited to participate as a researcher under Dr. V. Smith of the University of Windsor, Ontario, Canada. This research was within Projecto Pichincha, a regional development survey of this Ecuadorian province.

3 1 hectare is equal to 2.47 acres.

4 The study of machinery use in the cultivation of wheat in Pichincha Province was encouraged and actively supported by the Ministerio de Agricultura, Quito, Ecuador.


PROVINCES of ECUADOR
COLOMBIA
ESMERALDAS
CARCHI
IMBABURA
PICHINCHA
NAPO
MANABI
COTOPAXI
TUNGURAHUA
LOS RIOS
BOLIVAR
CHIMBORAZO
PASTAZA
GUAYAS
MORONA
SANTIAGO
CANAR
AZUAY
EL ORO
ZAMORA
LOJA
INTERNATIONAL BORDER
UNDEMARCATED BORDER
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0
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Figure 1

standards and decreased imports; second, Pichincha Province is one of the largest producers of wheat in the country, as well as a large importer of wheat; third, in relation to the production of other basic food crops, wheat is relatively mechanized; finally, the wheat producing areas of the province are such that the mechanization of this crop encounters great difficulties.

The areas specifically chosen in Pichincha Province were the three south eastern cantons of the Province: Mejia, Quito, and Ruminahui Cantons (Figure 2).[5] The three other cantons which make up Pichincha Province are Santo Domingo de los Colorados, Pedro Moncayo, and Cayambe. Santo Domingo Canton, lying entirely in a tropical area, produces no wheat and was therefore left out of the study. Cantons Pedro Moncayo and Cayambe held an additional one hundred wheat producers, but these areas were not included in the study because it was found after initial survey that they had corresponding characteristics to the three chosen cantons. Sufficient information for the study was obtained in Cantons Mejia, Quito, and Ruminahui, and therefore it was not felt necessary to include this additional area in the study of agricultural mechanization in Pichincha Province.

Objectives of the Study

The specific purpose of this study is to analyze the

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5 Cantons divide each province into smaller political administrative units. Pichincha Province is divided into six cantons.

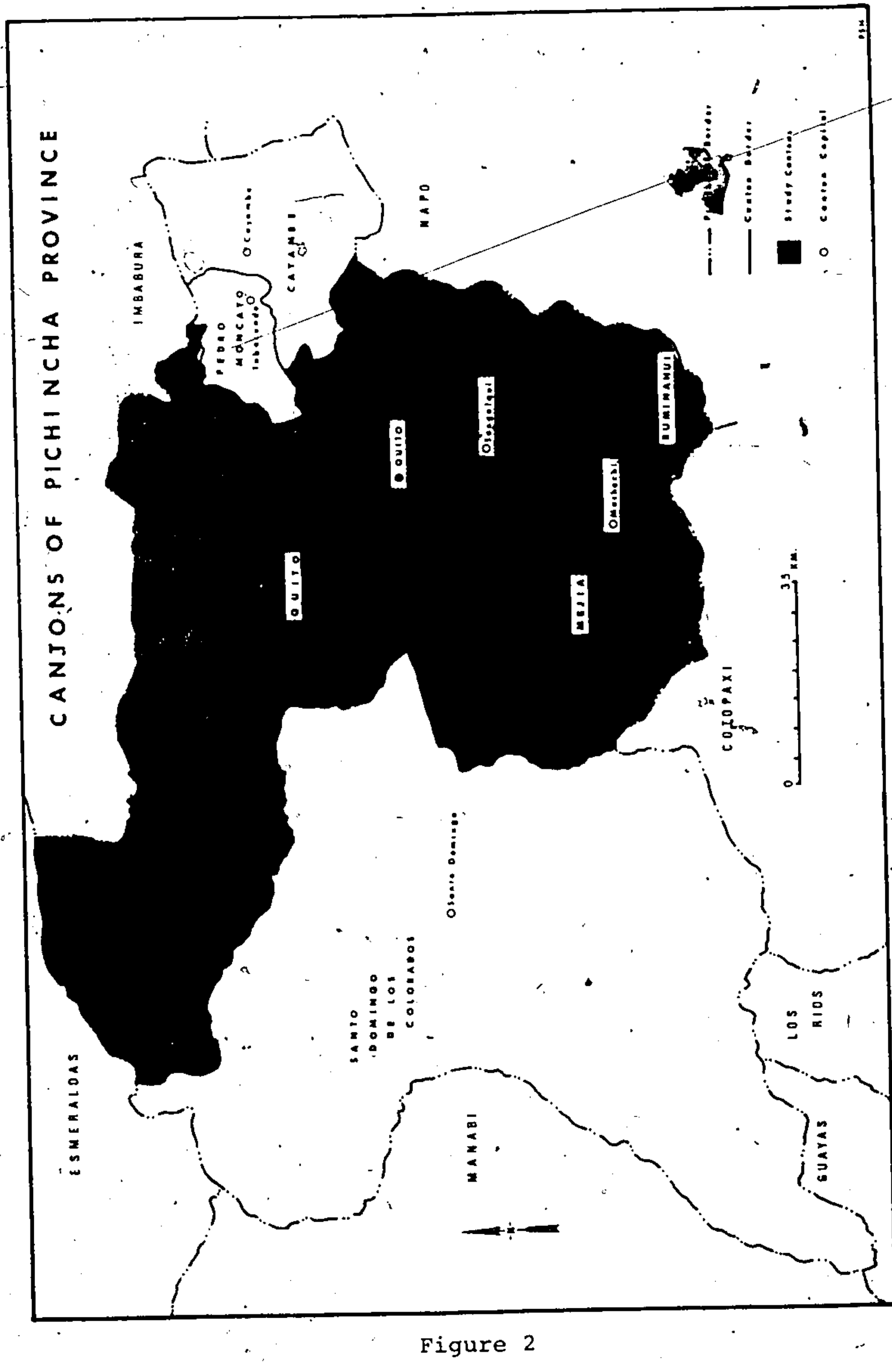
CANJONS OF PICHINCHA PROVINCE
ESMERALDAS
IMBABURA
NAPO
PEDRO MONCAYO
CAYAMBE
QUITO
RUMIÑAHUI
MEJIA
COTOPAXI
SANTO DOMINGO DE LOS COLORADOS
MANABI
LOS RIOS
GUAYAS
Canton Border
Study Canton
Canton Capital
0
35 KM.

Figure 2

mechanization of agriculture, particularly the mechanization of wheat production, in Cantons Mejia, Quito, and Ruminahui of Pichincha Province. Within this context there are two main objectives to achieve this result.

The first objective was to analyze the physical and agricultural characteristics which influence the degree of mechanization within the study area and to establish the parameters within which agricultural mechanization is possible. The wheat producing areas were also delimited from other agricultural areas to depict the actual area under consideration. It was also felt that there existed a need for a general discussion of the wheat situation in Ecuador, and particularly the situation within Pichincha Province and the study area. The wheat situation was discussed specifically in terms of production and production processes.

The physical characteristics of relief and topography, climate and soils were analyzed in terms of the possible effects they have on agricultural mechanization. The agricultural characteristics of farm size, wheat field size, farmer education, agricultural wages, technical expertise, distances to service centers, agricultural credit and extension were analyzed for the same reason.

The second objective of this study was to analyze the data gathered for this study in order to determine the close relationships existing among the variables. This procedure entailed a number of steps. The first was an inventory of the present use of agricultural machinery by each production stage. Included in this inventory were discussions on machinery use and the costs of using it for each stage. Alternatively, the non-mechanical methods employed and their associated costs were analyzed. This inventory considered all 140 wheat producers in Cantons Mejia, Quito, and Ruminahui. Second, differences in farm size, field slope and yields, among other factors, were analyzed through comparisons of the five levels of mechanization which exist in the study area. Third, total costs of using mechanical or non-mechanical methods of farming were analyzed in terms of levels of mechanization, farm size, wheat field slopes, and resultant yields. Fourth, farm size, hectares in wheat, hectares under cultivation, distances to service centers, and wheat field slopes were analyzed in reference to the effects these variables have upon levels of mechanization. The fifth stage was the analysis and discussion of the problems encountered by those wheat producers who do use agricultural machinery. The reasons why some producers do not use machinery at all, or use it only in certain stages of wheat cultivation, was analyzed in the sixth stage. Finally, the levels of agricultural mechanization, fertilizer use, farm size, and wheat field slope were analyzed in terms of the effects these variables have on wheat yields within the area.

Literature Review

In considering the relevant literature on farm mechanization, there appears to be a breakdown into two basic categories. The first category, and by far the most extensive, is concerned with the topic of agricultural machanization in general. This literature discusses the problems and benefits of farm mechanization. The second category is concerned with farm mechanization in underdeveloped areas, and while taking the general literature into consideration, deals with specific topics in underdeveloped areas such as the need for mechanization or the effects of mechanization upon the economy in general. A general review of the direction of this literature is thought to be useful in terms of the whole question of farm mechanization.

General Considerations on Mechanization

Mellor (1954: 16) felt that farmers make their decisions from a dependence upon the way they appraise and react to their environments, especially in response to some risk of uncertainty. While this in itself is not highly questionable, Mellor used it as a step to state than in essence the degree of mechanization is a "response to a need to increase the output per unit of labor." This is not the only factor dictating the degree of mechanization, and some agricultural economists have correctly pointed out that due to changes in the structure of modern agriculture, the degree of mechanization is a response to the desire for increased output in terms of yields (Hayami, 1971: 242).

Hayami feels the basic cause of world disequilibrium within agriculture is caused by the lag of underdeveloped areas of the world behind the developed ones in shifting from a resource-based agriculture to a science-based agriculture. For emphasis he cited an example of cereal production. In the developed nations cereal production increased by 123 million tons from 1964 to 1968, while the increase in the underdeveloped nations was only 52 million tons (Hayami, 1971: 242). For this reason, plus the fact that the lesser developed nations contain twice the population, the movement towards modern scientific agriculture in general must be at a more rapid rate. To date, productivity has been increased through a more widespread use of fertilizer and improved seed varieties, but further increases in productivity will be facilitated by the use of agricultural machinery (Mitchell, 1960: 37).

There has been a marked increase or interest in mechanization by many of the underdeveloped nations of the world (Kaneda, 1969; Chancellor, 1971; Clements, 1969). The rate at which farming is being mechanized has been increasing annually. There are widely differing views held by agricultural economists concerning the whole question of farm mechanization: first, there are those who feel the costs in terms of labor displacement and capital are too high a price to pay (Bose, 1969; Kaneda, 1969); second, there are those economists who find mechanization inevitable and point out the various systems under which machinery can be best supplied at the lowest cost (Chancellor, 1971); the third group are those economists who defend the need for mechanization in terms of the net benefits to the society as a whole (Inukai, 1970).

The introduction and development of high yielding varieties of seed into developing areas has brought the need for mechanization into focus. By using the more traditional farming methods, the yields which are possible through the use of improved seed have not been obtained. Since high yielding seed varieties are presently in use, or are being introduced to most developing areas, the question of whether to mechanize or not is partially academic (Schertz, 1968b: 2; Deutsch, 1972: 234).

Considerations of mechanization in agriculture are currently centered on the problem of how to mechanize farms whose owners lack the necessary capital, at the same time reducing labor displacing effects. In a study of small farm mechanization in Malaysia and Thailand, William Chancellor observed the adequacy of private hire services. Furthermore, he found an increase in employment occurred after introduction of machinery. Further employment was provided by the hiring of tractor operators, by increased employment in tractor part and implement manufacturing industries, and in mechanical repair shops. Previously, farmers had prepared their own land, hiring no additional help during these periods.

After hiring others to do their land preparation, farmers had extra time which was channelled into other productive farm activities such as growing fruit, thereby increasing their incomes (Chancellor, 1971: 847-853).

In Latin America the degree of farm mechanization is generally at a low level, but is showing signs of increasing (Clements, 1969; Streeter, 1972). The problems of agricultural mechanization are similar to those experienced in other areas, but of particular note is the general lack of government policy either encouraging or discouraging the mechanization of agriculture. This has led farmers to be apprehensive about deciding to mechanize. Farmers are also concerned with the high cost of farm mechanization. In Brazil, Clements showed that due to inefficient economies of scale, domestically produced tractors were actually more expensive than imported ones. In any case, neither of the tractors was cheap for the majority of the farmers to afford (Clements, 1969: 78). As other modern inputs requiring mechanization to obtain optimum production have already been introduced into Latin America, the whole question of mechanization must soon be remedied (Streeter, 1972: 16).

Problems and Advantages of Mechanization

The problems encountered in agricultural mechanization are varied and include physical, human, and agricultural considerations; and of these, probably the most important factors are the physical because they influence the degree or limit to which mechanization is possible to a much greater extent.

The topography or relief of an agricultural area has a great influence upon the use of machinery because problems arise due to steep slopes, dissected terrain influencing field size and shape, altitude, and the regularity of the land. Flat land, upon which machinery is thought to perform best, is defined by Hidore as land under three degrees of slope (1963: 84). In his study of the relationships between relief and grain farms in mid-western United States, Hidore found that the variations in flat land (less than 3°) explained the spatial location of the cash grain farms. As the angle of inclination increases, machines become increasingly unstable (Hidore, 1963: 89). Therefore, machinery must be specially adapted to work on steep slopes. This means that a greater amount of capital must be invested in farm modernization in areas of steep slopes. As farming machines become more complex and larger, the problem of slope stability increases (Mellor, 1954: 89).

An additional problem caused by relief is that there is a noticeable loss of power while working in mountainous areas. Tempany has shown that there is 3 to 3-1/2 per cent power loss for every additional one thousand feet in altitude (Tempany, 1958: 132). A thirty to forty horsepower tractor, advertised as a four-plough tractor, may not be able to meet this specification working at higher altitudes. Generally, imported farm equipment is not made or tested to meet the physical demands of tropical or mountainous areas.

Another problem related to relief is caused by rough, irregular land which also directly affects field size and shape. It is difficult to adapt machinery to the land, or land to mechanization, when it is cut into small sections by erosion or large rock outcrops. In actual time spent it is cheaper to use machinery for large regular shaped fields than for small irregularly shaped plots of land (Cervinka, 1971: 136). Rough irregular land and small irregular fields also lead to decreased maneuverability, while rough land by itself increases the possibilities of machine overturn (Mellor, 1954: 89). Reduced speeds will offset these problems somewhat, but will also reduce optimum utilization of agricultural machinery in terms of speedier operations. Fuel and repair costs will also be much greater when machinery is applied on either steep or irregular land. These higher operation costs will lessen any advantages of using agricultural machinery (Gordon, 1971: 251).

The type of soil will also directly influence the possible degree of mechanization. One problem arises in areas of poorly drained soils made up largely of clays. It is more difficult to adapt machinery to very wet soils, and special, possibly expensive innovations may be necessary. In areas where large amounts of stone or rock are found in the soil, the advantages of machinery use may be reduced because of lower possible speeds, higher repair costs, and a shorter working life for the piece of equipment (Hopfen, 1969: 29).

Many of the problems encountered in agricultural mechanization are due to human factors. In many instances the switch from animal power to tractor power constitutes a major jump in technology. Because of this there is a general lag in the possible progress due to a lack of adequately trained personnel to operate and repair the machinery (Mellor, 1954: 105). This is especially true today as we experience very rapid changes in design and capabilities of our agricultural machinery. Training a farm labor force to cope with modern technology may be justifiable from a societal point of view but the costs of such training to the individual farmer, in addition to the machinery costs, are often just too great (Deutsch, 1972: 234).

Other human factors directly or indirectly causing problems in agricultural mechanization, or influencing the degree of such mechanization are: credit availability, farmer education, and uncertainty of investment. These are problems which especially confront the smaller farmer (Coolman, 1960: 260-72).

Incomes of small farmers are usually low and not stable enough to finance machine investments, even if acceptance of new innovations is assumed. The uncertainty of investing in modern farm inputs, particularly farm machinery, is a heavier decision for a small farmer than for a large land holder; if the small land holder does have any money, he is often more cautious with it.

A lack of mechanization infrastructure and a detailed plan by the farmer of how he will use the machinery can often lead to problems once the machinery has been purchased. The level to which farm machinery can be utilized is of great importance in lowering the overall costs, both fixed and variable. The more tasks a particular machine can perform on a farm, the less its total costs because they can be spread out over a number of operations. While this process may raise variable costs such as fuel and repair costs, the fixed costs of capital infusion would be spread over a wider range, lowering total real costs (Fairbanks, 1971: 99).

Variations in regional progress of farm mechanization can be directly traced to regional differences in the costs of repairs and the availability and costs of replacement of parts. High costs and a lack of parts may lead to a retardation in the level of agricultural mechanization. Costs themselves will vary according to the number of individual farmers in an area who need mechanical services. The least costs occur in areas where there is a high concentration of mechanized farms (Mellor, 1954: 508-9).

Some of the benefits to be gained from farm mechanization are reduced time and labor required to complete each stage of the cultivation process, higher yields of better quality, savings in terms of land, and a simpler cropping system. There are also reduced costs in substituting machinery of a more modern nature, rather than replacing older types.

Table 1 depicts the time required to complete each stage of the cultivation process for wheat cultivation in man hours per acre. Accounted for here are cases where in England there is no use of machinery, limited use, and where a farm is fully mechanized (Wallace, 1960: 190; Barker, 1960: 140). As can be seen, there is a definite saving in time under full farm mechanization. This is of particular importance in areas where a short harvest season exists, and it is imperative to remove the crop from the land in a short period of time (Mellor, 1954: 96). The rate of work is then no longer dependent upon how long a man can work, but rather upon the length of time a machine can be used.

Table 1 Total Time (Man Hours/Acre) Spent in the Three Main Wheat Cultivation Operations at Three Varying Levels of Mechanization.

Agricultural Operation	No mech	Partial mech	Full mech[a]
Soil Preparation	10.25	3.75	3.35
Seeding, Fertilization and Weed Control	9.10	8.15	3.05
Harvest, Threshing[b]	24.75	25.10	8.20
Total Time	44.10	37.00	14.60

[a] average mechanical output.

[b] includes time spent in taking up and bailing the straw. Field disposal of the straw by fire requires 3.6 man hours/acre less in total for full mechanization level.

The use of machinery on a farm does not directly increase yields by itself, but it does allow for the proper applications of seed and fertilizer and better weed control and soil preparation. The speedier operations pointed out previously allow for earlier cropping and, therefore, greater yields at harvest time (Barker, 1960: 104). There is also less crop loss with more modern methods of handling. An example of this is the fact that a combine harvester loses less grain than a binder (or manual harvest) and a threshing machine. This attribute of more modern mechanical methods also leads to a decrease in crop damage due to overhandling. Not only quantity but quality of the crop may increase through the use of machinery on the farm.

Savings in terms of land use are made through the utilization of lands which were previously used for animal forage crops. Through the use of agricultural machinery, these areas can be converted into crop lands. This is of particular importance on small farms where the total amount of land for crop cultivation is small to begin with. The use of agricultural machinery also leads to a simpler form of cropping system because to be efficient, machinery requires larger areas under one crop. This may be an advantage in so far as the individual farmer will encounter less peak periods at the same time (i.e. harvests) where his attention will be required. Instead of cultivating five crops using manual labor, he may with the use of machinery cultivate only two crops with separate harvest periods, therefore having less peak periods to cope with at one time.

It may be less expensive for the agriculturalist to substitute newer mechanical methods when the need arises. An example of this is a farmer who presently uses a manual labor force to harvest grain and a threshing machine to separate the grain from the straw. If his old threshing machine has to be replaced, it may actually be less expensive to purchase a combine (harvester-threshing machine). Table 2 depicts price index changes in the United States from 1913 to 1937 for various machines and implements (Mellor, 1954: 73). These changes have occurred because of a relative decline in the demand for older types of machinery and implements compared to an increasing demand for the more modern methods.

Table 2 Changes in Prices of Selected Farm Machinery and Implements in the United States From 1913 to 1937.

Equipment	Price Index (1913 = 100)
Tractor	61.9
Plow (1 horse)	191.0
Plow (2 horse)	165.2
Plow (2 tractor)	134.8
Plow (3 tractor)	115.8
Plow (4 tractor)	98.2
Grain binder	159.1
Grain thresher	144.4
Combine (harvester-thresher)	74.4

As is evident from the literature, there are many pressing problems in the mechanization of agriculture. These problems are even more pronounced in the case of the small farmer. As Chancellor showed in his study of Thailand, farm mechanization can increase net development due to the linkages it has with other sectors of the economy. Other benefits of mechanization are at times difficult to translate into monetary terms, but nevertheless they are worthwhile objectives.

The mechanization of agriculture in Ecuador presents no difference in terms of problems and advantages from those encountered elsewhere, but there is a noticeable lack of literature in this area. The study of mechanization processes in the Andean areas of Ecuador will not only fill this gap in knowledge, but will also fill the need for more literature in the study of mechanization in areas of steep slopes.

Hypotheses

Utilizing the foregoing information and objectives, a number of hypotheses are suggested for the study of machinery in Pichincha Province, Ecuador. All are directly related to the present use of agricultural machinery in the production of wheat in the study area. The hypotheses are arranged from the causes of the level of mechanization in the area, the problems in its use, the reasons for its non-use, and finally to the implications of machinery use in wheat production.

The size of a farm has great control over the degree of mechanization that is possible. Mellor (1954: 89) feels the reasons for this are that small farms are more likely to be farmed using a high degree of manual labor, that there is a certain size farm below which it is not profitable to use agricultural machinery, and that small farmers are less trusting of new techniques. The amount of land actually used for wheat cultivation also directly affects the level of agricultural mechanization, as small fields retard the use of machinery. Even on large farms the use of machinery may not seem economically feasible when the area under wheat cultivation is relatively small (Gordon, 1971: 10). Slope inclination has a great effect upon many aspects of farm mechanization, modernization, and productivity in the study area. Hidore (1963), Gordon (1971), and Tempany (1958) feel that the level of agricultural mechanization will decrease; therefore, less costly techniques will be employed as the degree of slope increases. The distance to the nearest service center offering adequate repair and servicing for agricultural machinery is also of great importance (Fairbanks, 1971: 99). Throughout the study area variations in the level of mechanization are caused by these factors. This proposition will be tested as follows:

HO 1 Variations in the level of agricultural mechanization throughout the study area are a positive function of:

a) farm size,
b) wheat field size,
c) hectares under cultivation,
d) closeness to the nearest town,
e) closeness to the canton capital,
f) closeness to Quito,
g) low angle of slope of the wheat field.

A mechanization infrastructure must be established to realize the complete benefits of agricultural mechanization. Mellor (1954: 108-9) and Fairbanks (1971: 99) have shown that most frequent problems encountered in the use of agricultural machinery in developing areas are obtaining spare parts and at a reasonable cost. Obtaining repairs and other machinery services is often problematic as well. Steep and irregular land in the study area also causes problems for producers who use machinery. This will be tested as follows:

HO 2 The problems encountered by those producers who did use machinery in their agriculture are:

a) obtaining spare parts,
b) obtaining them at a reasonable cost,
c) obtaining repairs,
d) steepness or irregularity of their land.

The reasons why agriculturalists do not use machinery are often realistic (Gordon, 1971: 251); those often cited in Ecuador for the non-use of machinery are that hand labor is less costly to use, and that farmers do not have the necessary capital for machinery purchase in any case (Coolman, 1960: 260-72). Barroclough (1973: 67) has also cited that in many areas farmers' lands are either too steep or too irregular for the successful application of machinery. These propositions will be tested as follows:

HO 3 The reasons producers did not use machinery or did not use it in all stages of their wheat production are:

a) machinery was too expensive; they lacked the necessary capital,
b) hand labor was cheaper,
c) the land was either too steep or too irregular to use machinery.

Machinery use has a great effect upon wheat yields;

8

therefore, wheat yields tend to be greater on farms where machinery is used. Schertz (1968c: 2) and Deutsch (1972: 234) feel that this is due primarily to better seed bed preparation using machinery. Machinery is also of extreme importance in the even application of both fertilizer and seed, in the correct amounts (Barker, 1960: 104). Schertz also feels that there will be less loss of grain by using machinery than there would be using more traditional techniques. The amount of fertilizer used also has a direct bearing upon the return of wheat yields. Small farm size and steep slopes affect yields indirectly through the application of modern methods, as well as directly through farmers' attitudes (Mellor, 1954: 88). The variations in yields caused by these factors will be tested as follows:

> HO 4 Variations in yields throughout the study area are a positive function of:
>
> a) the property size,
> b) low angle of wheat field slopes,
> c) amount of fertilizer used,
> d) the level of agricultural mechanization.

Methodology

Field Work and Questionnaire

The field work for this study was completed from May to September, 1973 in Cantons Mejia, Quito, and Ruminahui of Pichincha Province, Ecuador. After an initial survey of the literature and after discussions with personnel in the

Ministerio de Agricultura, it was found that there had never been a comprehensive study done on the mechanization of wheat production, or of any other crop in the study area.

As an initial starting point, the Ministerio de Agricultura provided a list of all wheat producers, <u>trigueros</u>, both large and small, who had produced wheat in the three study cantons during the 1973 production year. Personal interviews were conducted with all 140 of these producers, and using a questionnaire, answers were requested to both closed and open ended questions. The level of mechanization of these producers varied from full mechanization to partial mechanization to no machinery at all.

The questionnaire used sought information relevant to the use of machinery and to the production of wheat generally (Appendix A). The questions were drafted after consultation with the head of the agricultural production section of the Ministerio de Agricultura, the head of the Programa Nacional de Granos (National Grain Program), and numerous extension agents who work with the wheat producers in Pichincha Province.

The main responses sought were those directly related to the use of agricultural machinery, those indirectly affecting this use of machinery, and factors which influenced the wheat yields. The first group of specific questions on directly related factors included the types of machinery and implements employed, the cost of using machinery for the preparation, seeding, and harvesting of the land, and the cost of <u>tractoristas</u> (tractor drivers). An open question was asked on the problems farmers had in using machinery. Alternatively, if producers used partial or no machinery in the production process, responses were sought on wheat methods they did employ and the costs associated with these alternative methods. An open question was asked on the reasons why farmers did not use machinery or did not use it in all of the production steps.

The second group of responses requested were those which indirectly affected the use of machinery or wheat production. These included distance to nearest service center, farm size, hectares cultivated, hectares in wheat, amount of fertilizer used, and yields. The degree of slope of the wheat fields was measured. Distance to the nearest service center was selected as a variable because of the importance of repair and fuel services in the use of agricultural machinery (Fairbanks, 1971). Farm size, hectares cultivated, and hectares in wheat were selected because it was felt there was a strong relationship between farm and field size and the use of agricultural machinery (Mellor, 1954). The amount of fertilizer used was selected because of its direct influence upon wheat yields, and because it was felt that a correlation exists between the use of this modern farm input and the use of machinery (Barker, 1960). Yield was selected as a variable for this same reason. The degree of field slope was measured because of the high correlations thought to exist between it and the use of agricultural machinery (Hidore, 1963). The angle of slope of the wheat fields was measured using a Dietzgen field clinometer. These average degrees of slope were compiled by the author through visits to each producer's wheat field.

Secondary sources that were used included various Ecuadorian government publications concerning wheat production, and to a lesser extent, publications on modern farm inputs and machinery use as this type of publication is generally lacking. Various articles and books of agricultural machinery use were also consulted for this study, although few were found to be of direct relevance to the Ecuadorian agricultural situation.

Analysis

Map interpretation was emphasized in outlining the physical and agricultural characteristics of Pichincha Province which influence the use of agricultural machinery and the production of wheat. Each farm interviewed was located and plotted on topographic maps for the purpose of exact location in terms of both horizontal and vertical positions.[6] These maps were used to delimit the wheat producing areas from other agricultural areas. The maps were also used to show altitudinal location of the study farms by size, yield, and level of mechanization. Interpretation of other available maps was used in the delimitation of various

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6 Topographic maps of the study area at the scale of 1:25,000 and 1:50,000 were provided by the Instituto Geografico Militar, Quito, Ecuador.

physical characteristics such as soil, relief, and climate which affect wheat production and machinery use in general.

An analysis was also undertaken of the agricultural factors of the area which influence agricultural mechanization. Among these are farm size, characteristics of the agricultural population, fertilizer use, distances to service centers, and agricultural and credit services. The analysis was in terms of a review of the present situation and how these factors influence the possible use of agricultural machinery. This information was outlined and compared using graphing techniques and means and standard deviations. There was also a comparison of large and small farms and users of mechanical and non-mechanical farm equipment. These are all important considerations of general farm modernization and specifically of agricultural mechanization, and were therefore imperative considerations for this study.

To illustrate the current level of agricultural mechanization in the study area, a simple inventory of the types of machinery was graphically presented for each stage of the wheat cultivation process. Alternatively, graphical analysis was also used to depict the alternative methods employed by those producers who used no machinery or used it in only a limited manner. The costs at each stage were analyzed by the type of production process utilized. A specific comparative analysis was performed on the factors such as yields, farm size, and fertilizer use, as the degree of agricultural mechanization changes within the study area.

The total cost of using mechanical or non-mechanical methods of production was analyzed using simple correlation analysis and graphing techniques. This analysis was employed to determine the relationship between levels of mechanization, farm size, wheat field slope, and yields, and the total cost of using machinery at varying levels within the study area.

In analyzing the first and the fourth hypotheses of this study, stepwise multiple regression analysis was employed to show the variations caused in the two dependent variables - yields and levels of agricultural mechanization - by the various independent variables chosen for each regression.

The problems encountered by agriculturalists in using machinery on their farms (HO2) were presented and graphically analyzed, as were the reasons why some farmers did not use machinery at all (HO3). The analysis of these two hypotheses was felt to be important in terms of revealing the structural weaknesses within the agricultural sector of this area.

CHAPTER II PHYSICAL AND AGRICULTURAL INFLUENCES

The physical and agricultural environments of an area influence the ability to mechanize agriculture. Physical factors such as topography, climate, soil type and quality directly influence the degree of mechanization which is economically possible in any given area. The agricultural aspects affect the possible degree of mechanization both directly and indirectly. For example, farm field size is one factor among others that directly influences the degree of farm mechanization. The characteristics of the agricultural population and distances to service centers, as well as credit and extension services, are among the factors which indirectly influence the mechanization of agriculture. Within the three cantons under study these characteristics and others both physical and agricultural influence the degree and type of agricultural mechanization employed. A review of these factors is important as a preliminary foundation for the study of agricultural mechanization in Pichincha Province, Ecuador. A brief résumé of the study crop, wheat, was presented in order to outline this crop's production in Ecuador, particularly within the study area. Wheat was chosen because of its importance to Ecuador's national economy, and because it is a crop which is highly mechanized in relation to other crops. The study area itself was discussed in some detail, defining its precise site and situation.

The Study Area

Pichincha Province has an area of 16,037 kilometers, 11,545 kilometers of which consist of the western piedmont and coastal areas (Cevallos, 1958: 105; Basile, 1964: 22). Only twenty per cent of the province consists of land under ten degrees of slope. A further twenty-three per cent has slopes between ten and twenty degrees (Programa, 1973: n.p.).

The area of concern for this study is the intermontaine basin area of the Sierra, in particular the Quito Basin (Figure 3). This basin is one of fifteen such basins that extend in a narrow belt along the Sierra of Ecuador from Colombia in the north to Peru in the south (Basile, 1964: 11). The basin is the largest of the Ecuadorian basins with an average width of forty-eight kilometers, and average altitude of 2,500 meters (Basile, 1964: 24).

In 1961 wheat producing areas of Pichincha Province were estimated to cover 2,839 square kilometers, making up seventeen per cent of the province's land use (Cordovez, 1961: 151). Through advances in seed breeding and the use of fertilizer, many additional areas have been cultivated in wheat, resulting in 3,500 square kilometers of wheat producing areas in the Quito Basin in 1965.

Figure 4 shows the wheat producing areas of the three cantons under study. Within this area wheat is now grown

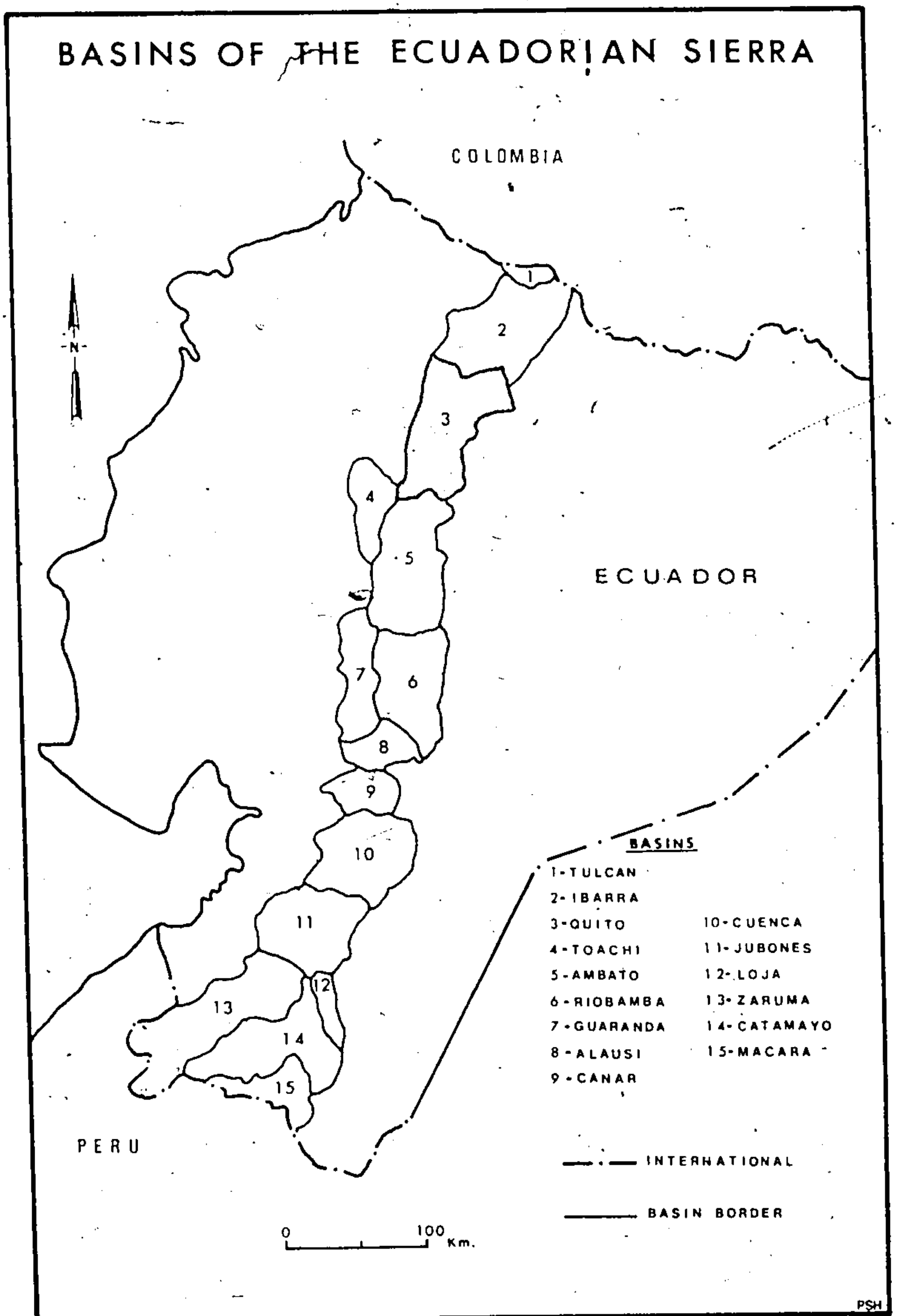
BASINS OF THE ECUADORIAN SIERRA
COLOMBIA
ECUADOR
PERU
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
BASINS
1-TULCAN
2-IBARRA
3-QUITO
4-TOACHI
5-AMBATO
6-RIOBAMBA
7-GUARANDA
8-ALAUSI
9-CANAR
10-CUENCA
11-JUBONES
12-LOJA
13-ZARUMA
14-CATAMAYO
15-MACARA
INTERNATIONAL
BASIN BORDER
0
100
Km.
PSH

Figure 3

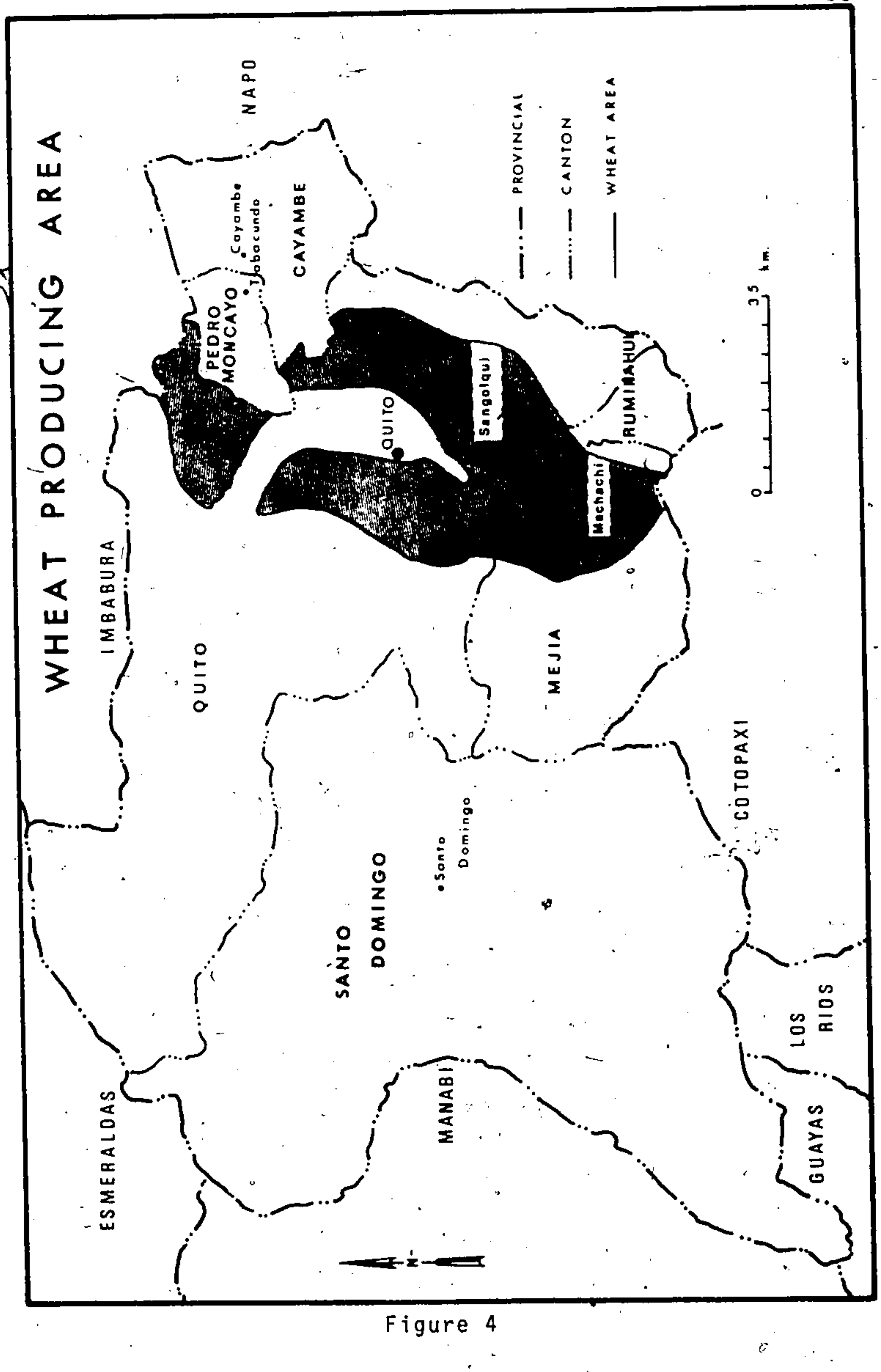
WHEAT PRODUCING AREA
NAPO
CAYAMBE
Cayambe
Tabacundo
PEDRO MONCAYO
QUITO
Sangolqui
Machachi
RUMIÑAHUI
IMBABURA
QUITO
MEJIA
COTOPAXI
Santo Domingo
SANTO DOMINGO
LOS RIOS
GUAYAS
MANABI
ESMERALDAS
PROVINCIAL
CANTON
WHEAT AREA
0
35 km.
N

Figure 4

in parts of the basin which were previously used for less temperate agricultural systems. It should be noted, however, that not all of the areas depicted as wheat areas are used exclusively for the cultivation of this crop.

Wheat Production in Ecuador

There has been a general increase in national wheat production in Ecuador from 1950 to the present, but there has also been a corresponding increase in the importation of this commodity to satisfy the ever increasing demand for wheat. Within the time period from 1950 to 1970 the average area devoted to wheat production increased from 141,000 hectares to 175,000 hectares; however, by 1973 the area in wheat had decreased to 145,000 hectares (Miranda, 1971: 7; Programa, 1973: n.p.). Consequently, average annual wheat production growth rates for 1950 to 1960 and 1960 to 1973 were 6.3 per cent and 2.6 per cent respectively (Zuvekas, 1973: 73; Programa, 1973: n.p.). The lowest national growth rate for wheat production was registered between 1968 and 1970 when there was only a 1.4 per cent annual growth rate over the previous period (Zuvekas, 1973: 73). Based on government projection, wheat production is expected to increase five per cent annually for the remainder of the 1970's (Programa, 1973: n.p.).

Table 3 illustrates the above point, showing national wheat production, imports of wheat, and the total consumption of this crop between the years 1950 and 1972. There is

Table 3 National Production and Imports of Wheat in Tons (1950-73)

Year	National Production	% Change	Imports	% Change	Total
1950	20,016	---	6,773	---	26,789
1951	27,450	37	5,186	-23	32,636
1952	25,895	-5	15,676	202	41,571
1953	26,277	2	16,877	8	43,154
1954	33,927	29	90,387	435	124,314
1955	42,153	25	63,522	-29	105,675
1956	40,596	-4	66,601	5	107,197
1957	35,415	-13	44,152	-34	79,567
1958	39,040	10	41,219	-7	80,259
1959	47,491	22	52,006	26	99,597
1960	58,375	23	40,502	-22	98,877
1961	80,470	38	40,000	1	120,470
1962	89,800	12	50,000[1]	2	139,800
1963	97,520	9	50,000[1]	0	147,520
1964	103,040	6	50,000[1]	0	153,040
1965	108,100	5	50,000[1]	0	158,100
1966	68,685	-58	50,000[1]	0	118,685
1967	72,300	5	50,000[1]	0	122,300
1968	81,940	12	60,727	21	142,667
1969	78,325	-4	63,000	4	141,325
1970	90,375	15	57,000	-9	147,375
1971	80,350	-6	90,015	57	174,365
1972	72,300	-14	110,000	22	182,300

1 Average imports 1960 to 1966.

(Source: Amunatiqui, 1967: 70; Grain and Feed, 1968: 7; Haviland, 1971: 6; Miranda, 1971: 7; Zuvekas, 1970: 33).

an overall significant increase in national production during these years, but because of rapid increases in consumption, imports show an even more significant increase in the same period. Of particular note is 1952, 1954, and 1971 where increases in imports of 202 per cent, 435 per cent, and 57 per cent were registered respectively. Following a massive push by the government in 1958-9 to make the nation self sufficient in wheat, national production increased significantly in the first five years of the 1960's. These advances faltered after 1965 with a negative change of fifty-eight per cent between 1965 and 1966 when production fell from 108,000 tons to 68,685 tons annually, and a twenty per cent decrease in domestic production between 1970 and 1972. This situation resulted, in part, from increased production expenses and the low support price of wheat compared to other crops such as barley which had better profit margins. Wheat consumption in Ecuador has risen from 26,789 tons in 1950 to 182,300 tons in 1972, nearly a seven fold increase.

Wheat Production in the Study Area

Figure 5 shows the location of the 140 wheat producers in the three cantons included in the study. There are forty-six (32.9%) wheat producers in the six parishes of Canton Mejia, four (2.9%) producers in two parishes of Canton Ruminahui, and ninety (64.2%) wheat producers in sixteen parishes of Canton Quito.

Wheat yields vary considerably throughout the study

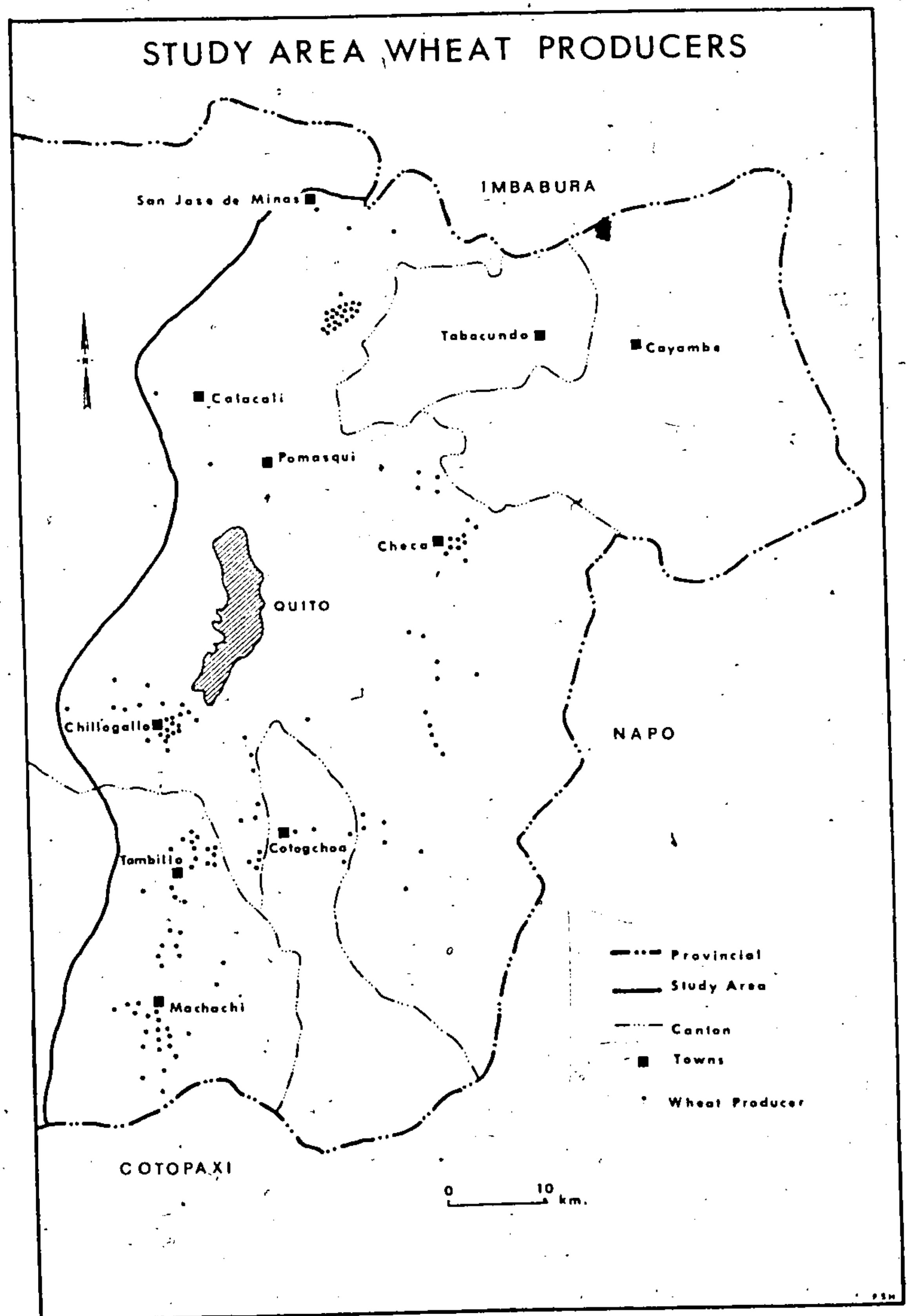
STUDY AREA WHEAT PRODUCERS
IMBABURA
San Jose de Minas
Tabacundo
Cayambe
Calacali
Pomasqui
Checa
QUITO
Chillogallo
NAPO
Cotogchoa
Tambillo
Machachi
Provincial
Study Area
Canton
Towns
Wheat Producer
COTOPAXI
0
10
km.

Figure 5

area (Figure 6). The greatest number of producers, 78(55%), produce less than twenty quintals per hectare of wheat sown. Of this total, eighteen producers had yields of less than ten quintals per hectare, thirty produced ten to fifteen quintals, and the remaining twenty-seven produced sixteen to twenty quintals of wheat per hectare. Twenty wheat producers had yields between twenty-six and thirty quintals, while only seven had yields of greater than fifty quintals per hectare. The mean yield for the entire study area was 25.92 quintals per hectare with the least yield for one hectare of land being five quintals and the greatest yield, produced in Canton Mejia, being ninety quintals per hectare. This maximum yield was nearly four times the area's mean yield, and was obtained under full agricultural mechanization.

Mechanization of Wheat Production

The Ecuadorian Government maintains that through the use of sufficiently modern agricultural methods, wheat cultivation can still be a profitable enterprise at the current market price. Tables 4 and 5 show government calculated estimates of costs and possible profits under partial and no mechanization. These figures are widely circulated to show that no increase in the basic wheat support price is necessary at this time if farmers will adopt modern methods of wheat production. The circulation of these estimates had led to an increase in the use of machinery as well as other agricultural inputs. Basically these tables show that with

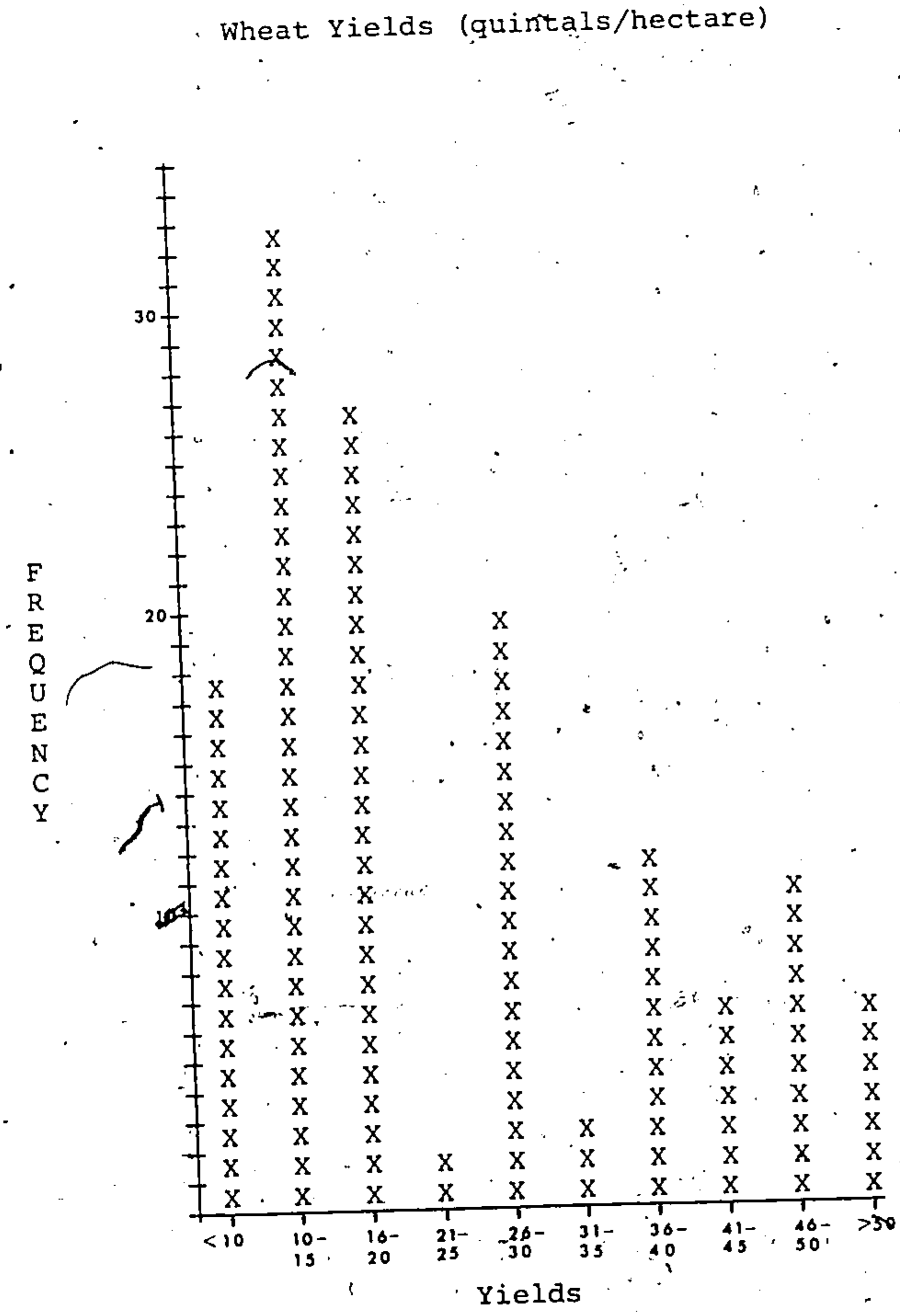
Wheat Yields (quintals/hectare)
FREQUENCY
30
20
10
<10
10-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
>50
Yields

Figure 6

Table 4 Typical Costs and Benefits of Wheat Cultivation When Partially Mechanized (1972)[1,2,3]

Type of Cost	Cost[4] (S/Ha)[5]	Cost[4] (S/QQ)[6]	% of Total Cost
Land rent	300.00	8.57	11.02
Cultivation costs:			
Soil preparation	720.00	20.57	26.45
Seed	280.00	8.00	10.29
Fungicides	36.00	1.03	1.32
Fertilizer & application	312.00	8.91	11.46
Herbicide & application	70.00	2.00	2.57
Seeding	36.00	1.03	1.32
Mechanical harvest	350.00	10.00	12.86
Other costs:			
Transportation	47.50	1.36	1.75
Administration	215.15	6.15	7.91
Technical assistance	107.57	3.07	3.95
Unforeseen costs	247.42	7.07	9.09
Total costs of production	2,721.64	77.76	100.00

1. Based on yield of 35 quintals per hectare.
2. Based on a value of S/100 per quintal.
3. Payment for 35 quintals per hectare at S/110 is S/3850.00
   - Relation of costs to benefits: 1:1.41
   - Profit: S/1128.36 per hectare.
4. 25 sucres (S/) = $1.00 U.S. (1973).
5. Sucres per hectare.
6. Sucres per quintal of wheat harvested.

(Source: Programa Nacional de Granos, 1973: n.p.; INIAP, 1973: 23-24).

Table 5 Typical Costs and Benefits of Wheat Cultivation When No Mechanization is Used (1972)[1,2,3]

Type of Cost	Cost[4] (S/Ha)[5]	Cost[4] (S/QQ)[6]	% of Total Cost
Land rent	300.00	15.00	13.57
Cultivation costs:			
Soil preparation	315.00	15.75	13.93
Seed	260.00	13.00	11.50
Fungicide	24.00	1.20	1.06
Fertilizer & application	666.00	33.30	29.46
Seeding	24.00	1.20	1.06
Harvest	154.00	7.70	6.81
Other costs:			
Transportation	40.00	2.00	1.77
Administration	180.30	9.02	7.98
Technical assistance	90.15	4.15	3.99
Unforeseen expenses	207.34	10.37	9.17
Total costs of production	2,360.79	113.05	100.00

1. Based on yield of 20 quintals per hectare.
2. Based on value of S/110 per quintal.
3. Payment for 20 quintals per hectare at S/110 is S/2220.00
   - Relation costs to benefits: 1:0.97
   - Loss: S/60 per hectare.
4. 25 Sucres (S/) = $1.00 U.S. (1973).
5. Sucres per hectare.
6. Sucres per quintal of wheat harvested.

(Source: Programa Nacional de Granos, 1973: n.p.; INIAP, 1973: 23-24).

all costs, estimated yields, and the current market price, partially mechanized farmers can realize a fifty per cent profit while the non-mechanized farmer can hope at best only to break even growing wheat.

During the years between 1967 and 1971 there were an average of 79,336 hectares under wheat cultivation in Ecuador. Full mechanization processes were used on 2,600 hectares (3%) of this total, while a further 7,300 hectares (9%) were partially mechanized, and 69,236 hectares (88%) were farmed without the use of any machinery at all. In Pichincha Province, in contrast to the national situation, partial mechanization processes were most prevalent in accounting for seventy-nine per cent of the country's total users of partial mechanization. The second most common level of mechanization in Pichincha Province was full mechanization; this province accounted for sixty-one per cent of all full mechanization users within the country, while users of no machinery within the province accounted for only twelve per cent of the national total (Programa, 1973: n.p.).

Table 6 shows the number of wheat producers on the national level by the size of their farms and the cultivation methods employed at each stage of the wheat cultivation process. The largest number of producers, 23,860, have farms of less than ten hectares and only 1,640 (7%) of these use machinery for the preparation of the soil for wheat cultivation. The greatest users of machinery for soil preparation are those producers having farms of greater than one thousand

Table 6 Size and Number of Wheat Producing Farms By Their Level of Mechanization in Ecuador

Size (HAS)	Number	Soil Preparation			Seeding			Cutting			Threshing		
		Mach	%Group	Man	Mach	%Group	Man	Mach	%Group	Man	Mach	%Group	Man
< 10	23,860	1640	7.0	22,220	0	0.0	23,860	0	0.0	23,860	3730	15.0	20,130
10-20	3,080	20	1.0	3,060	0	0.0	3,080	0	0.0	3,080	260	8.0	2,820
20-50	1,840	80	4.0	1,760	0	0.0	1,840	10	1.0	1,830	280	15.0	1,560
50-100	258	118	45.0	140	16	6.0	242	28	10.0	230	239	92.0	19
100-500	289	190	65.0	99	51	17.0	238	81	27.0	208	271	93.0	18
500-1000	51	40	78.0	11	18	35.0	33	18	35.0	33	46	90.0	5
> 1000	38	33	90.0	5	19	50.0	19	22	58.0	16	37	98.0	1
Total	29,416	2121	----	27,295	104	----	29,312	159	----	29,257	4863	----	24,553

(Source: Programa Nacional de Granos, 1973: n.p.)

hectares, with ninety per cent of their group using machinery at this stage. The group using the least machinery for soil preparation are those producers with farms of ten to twenty hectares, as only one per cent of the 3,080 producers in this category use machinery.

Much of the seeding of wheat in Ecuador is manual, particularly on small farms. Table 6 indicates that in Ecuador there is no use of machinery for seeding on farms of less than fifty hectares. The largest users of machinery at this stage are producers who have farms of a size greater than one thousand hectares, where fifty per cent of the group use seeding machines. In terms of actual numbers, those producers located on one hundred to five hundred hectare farms use the most machinery for seeding, but the number of producers in this category is greater than the larger farm sizes combined. The situation for wheat cutting is nearly identical, but this categorization does not refer to the use of combines, only mechanical wheat cutters.

The threshing operation includes producers utilizing a threshing machine or a combine. It is unfortunate that the 1972 inventory of mechanization did not separate these distinct forms of mechanization to enable better analysis of the situation for that year. Table 6 shows that producers on farms of less than ten hectares were the greatest users (in actual numbers) of mechanical devices in this stage of wheat cultivation. From general field observations, it is probable that a majority of these farmers (3,730) used only a threshing machine, but the available government statistics are not divided into such categories. In terms of percentages, producers on farms of one hundred to five hundred hectares, and producers having more than one thousand hectares have high percentages (ninety-three and ninety-eight per cent respectively) of their groups using machinery for the wheat harvest. Again it is probable that the majority of these producers use a combine, but again this table gives no indication.

In conclusion, table 6 shows that only 2,141 of the total 29,416 wheat producers in Ecuador used machinery for land preparation; 104 used machinery for seeding; 159 used machinery for cutting operations, and 4,863 used machinery for threshing purposes on their farms. In 1970 the use of machinery in Pichincha Province was more widespread and has since increased within the area (Programa, 1973: n.p.). As indicated in the preceding discussion, there exist fundamental problems associated with wheat cultivation in Ecuador. The necessity of solving these problems has been considered in terms of the low domestic production which causes a drain on foreign exchange because of the increasing need for imports. While there have been problems, periodic gains have been made, and the need to maintain these increases in domestic production is self-evident. The national mechanization of wheat production has improved in the last few decades and is continuing to do so. The situation of wheat production within the study area has been very similar to that of the whole country, but this area has generally led the nation in the use of agricultural machinery. The level of agricultural mechanization has a large scope for expansion in this area, but the physical and agricultural setting limit this growth in the use of agricultural machinery.

Physical Influences in the Study Area

Both the production of wheat and the use of agricultural machinery in Pichincha Province are influenced by the physical factors of topography, climate, and soils. Topography has the most pronounced influence upon the use of agricultural machinery within the study area per se, while the climate and the soils of the area affect its use to a lesser degree. All three of these characteristics influence the natural and physical production of wheat in the study cantons.

Relief and Topography

The relief and topography of an area directly influence the level of agricultural mechanization. This is especially true of the study area because both the local relief and the general regional physiography act to forestall advances in the agricultural mechanization of the area. The Quito Basin is rimmed on the east and on the west by two transverse ridges, the Cordillera Oriental on the east and the Cordillera Occidental on the west.

The Sierra itself is divided into small isolated compartments or individual basins, <u>hoyas</u>, by volcanos or volcanic outpourings which form barriers called <u>nudos</u> (Butland, 1960: 184; Basile, 1964: 20). In the Quito Basin the <u>Nudo de Cajas</u> separates the basin from Ibarra Basin to the north, while the <u>Nudo de Tiopullo</u> separates it from the Latacunga-Ambato Basin in the south. The basin is of a rough rectangular shape with its four corners marked by volcanic peaks, some of which are active (Figure 7).[7]

Figure 8 shows a generalized portrayal of the topography of the Quito Basin, and as can be seen, the altitudes and relief vary considerably from one area to another. Figure 9 shows east-west and north-south profiles of the basin taken from the topographic map. The basin floor can be seen to slope gradually from the south to the north; as a result of this the Rio Guallabamba originates as the Rio San Pedro on the slopes of Mount Illiniza and drains north through the entire area, obtaining water mainly from the west (Figure 10). This river finally drains into the Pacific Ocean.

Slopes, which are the common feature of this area, are often extremely steep and as a result, the basin itself is dissected by numerous streams, valleys, ravines, and canyons, especially north of Quito in the wheat producing areas

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7 These peaks are Mount Cayambe (19,000 feet), Mount Cotopaxi (19,347 feet), Mount Illiniza (17,274 feet), and Mount Mojanda (14,030 feet). Other mounts ringing the basin are Mounts Corazon and Pichincha in the western cordillera and Mounts Punto, Filo Corrales, and Cubillan in the eastern cordillera.

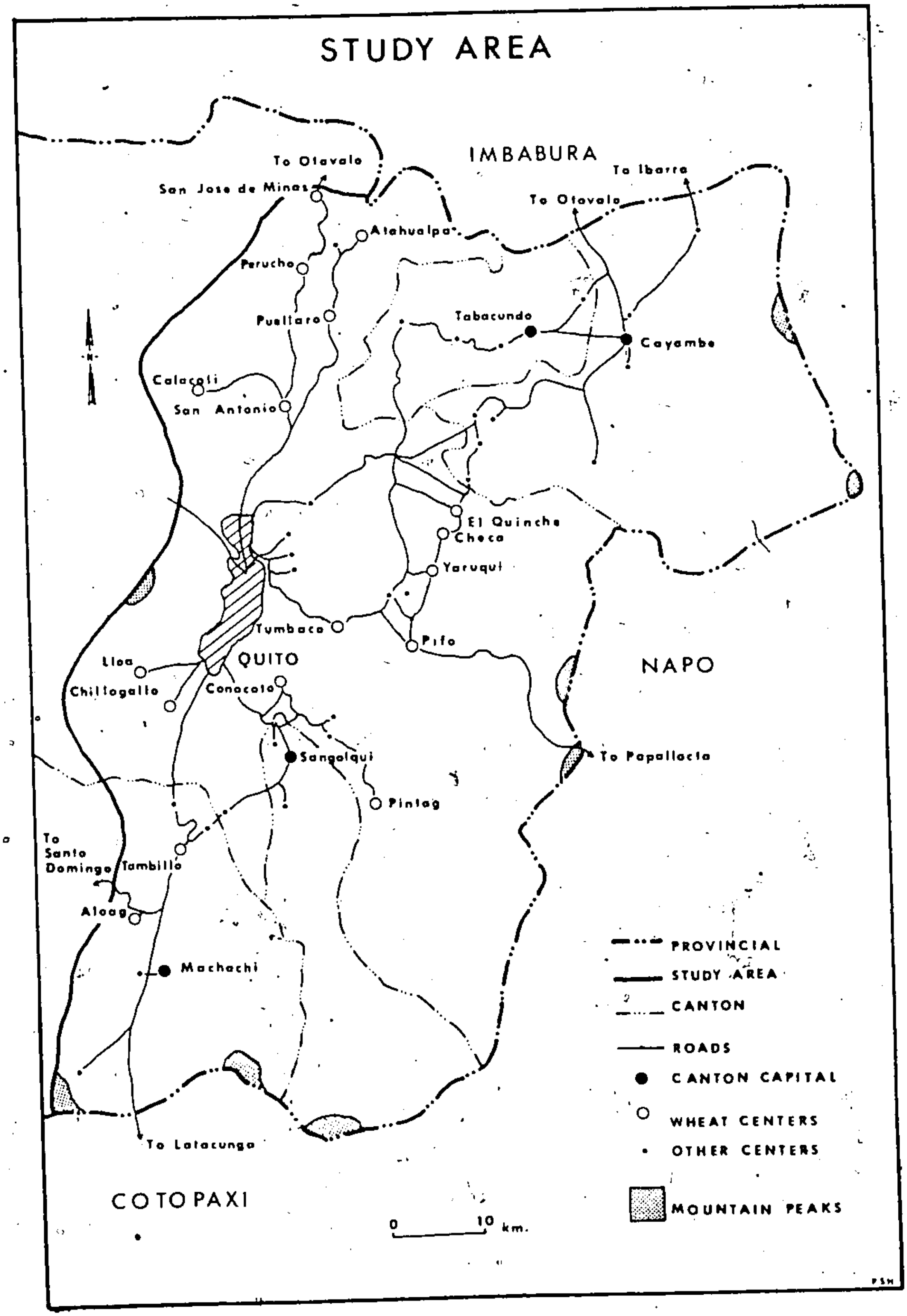
STUDY AREA
IMBABURA
To Otavalo
San Jose de Minas
Atahualpa
Perucho
Puellaro
Tabacundo
Cayambe
To Ibarra
To Otavalo
Calacali
San Antonio
El Quinche
Checa
Yaruqui
Tumbaco
Pifo
QUITO
Lloa
Chillogallo
Conocoto
Sangolqui
Pintag
NAPO
To Papallacta
To Santo Domingo
Tambillo
Aloag
Machachi
To Latacunga
COTOPAXI
PROVINCIAL
STUDY AREA
CANTON
ROADS
CANTON CAPITAL
WHEAT CENTERS
OTHER CENTERS
MOUNTAIN PEAKS
0
10 km.

Figure 7

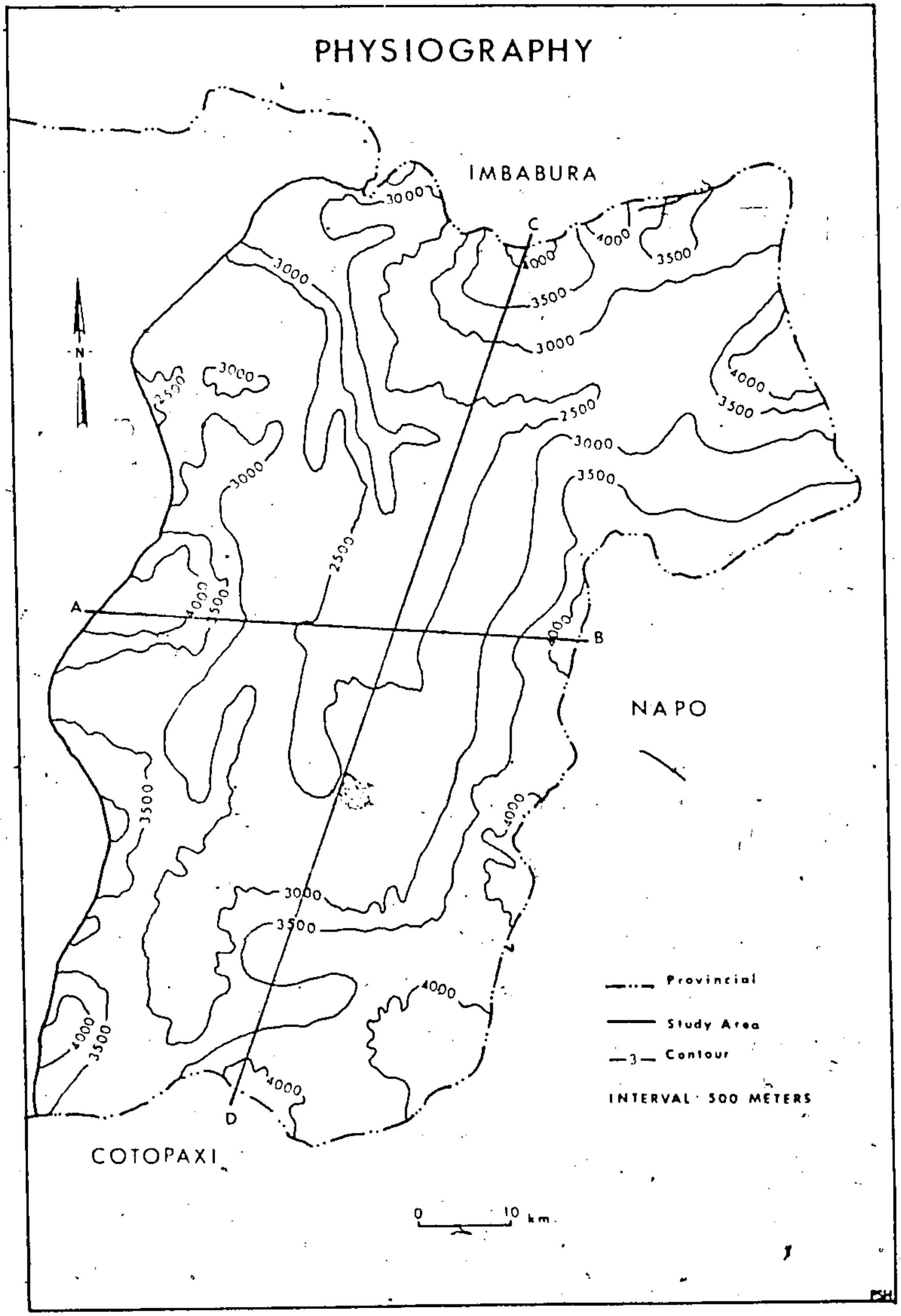
PHYSIOGRAPHY
IMBABURA
NAPO
COTOPAXI
N
A
B
C
D
3000
2500
3500
4000
Provincial
Study Area
3 Contour
INTERVAL 500 METERS
0
10 km

Figure 8

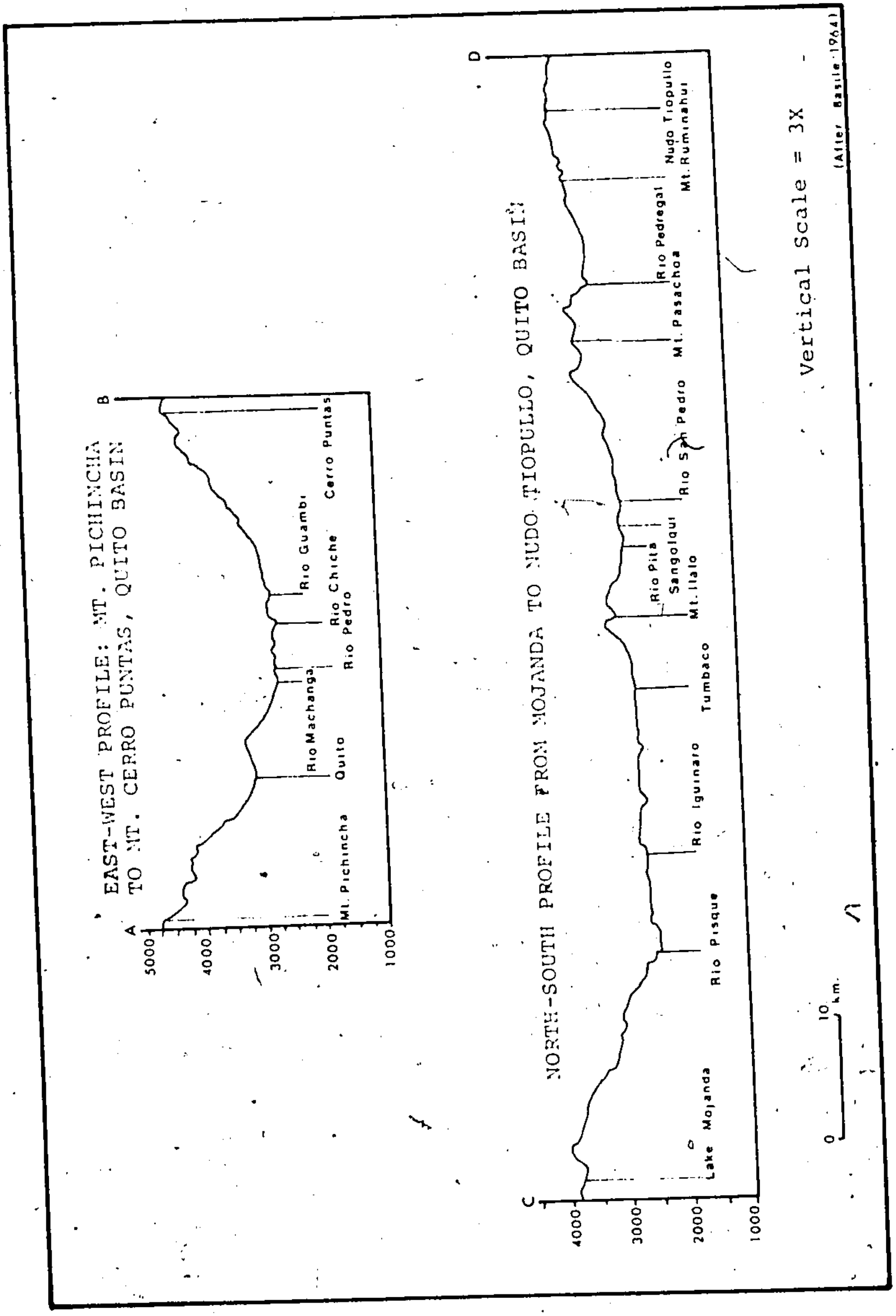
EAST-WEST PROFILE: MT. PICHINCHA
TO MT. CERRO PUNTAS, QUITO BASIN
A
B
5000
4000
3000
2000
1000
Mt. Pichincha
Quito
Rio Machanga
Rio Pedro
Rio Chiche
Rio Guambi
Cerro Puntas
NORTH-SOUTH PROFILE FROM MOJANDA TO NUDO TIOPULLO, QUITO BASIN
C
D
4000
3000
2000
1000
Lake Mojanda
Rio Pisque
Rio Iguinaro
Tumbaco
Mt. Ilalo
Sangolqui
Rio Pita
Rio San Pedro
Mt. Pasachoa
Rio Pedregal
Mt. Ruminahui
Nudo Tiopullo
Vertical Scale = 3X
0
10
km.
(After Basile 1964)

Figure 9

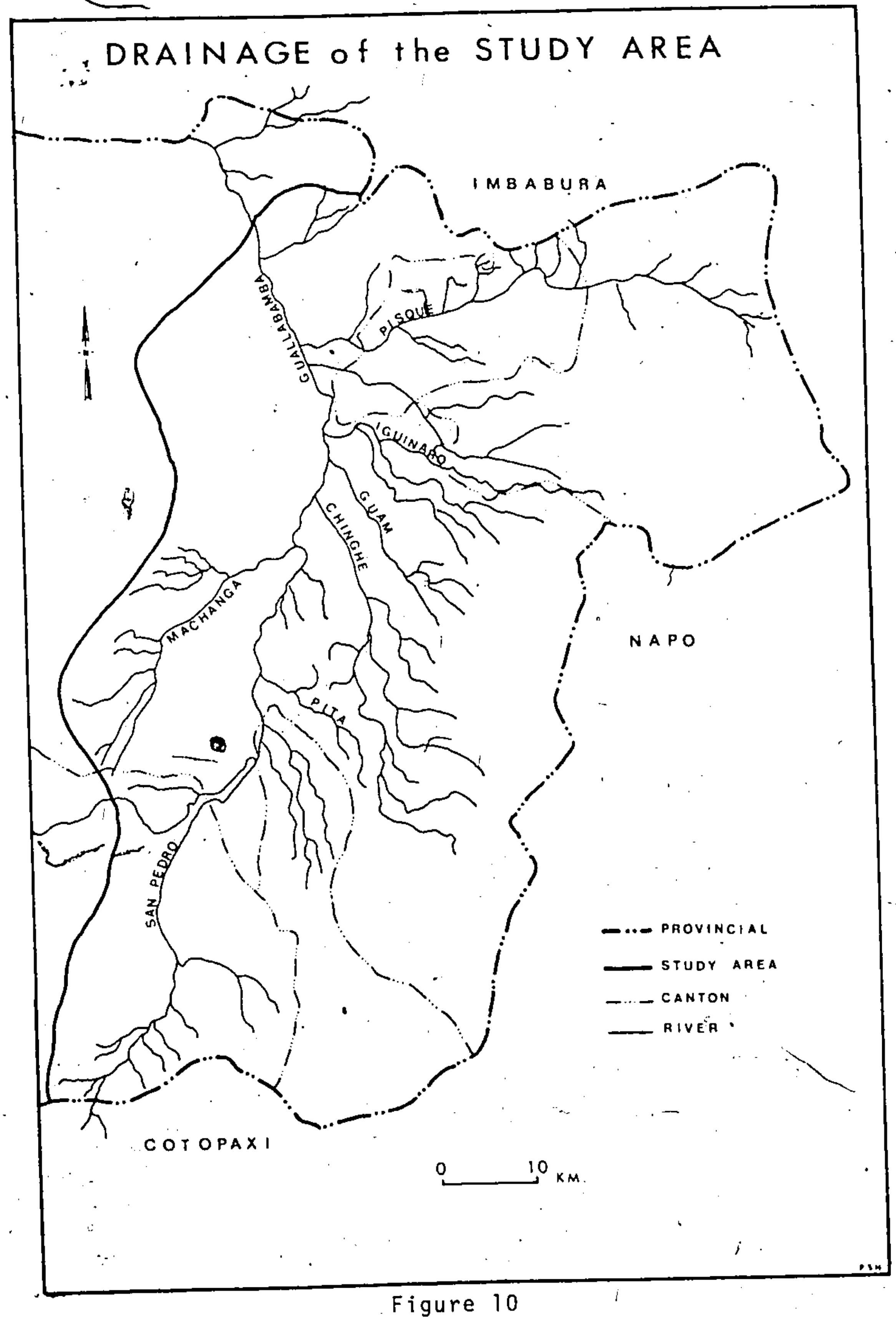
DRAINAGE of the STUDY AREA
IMBABURA
NAPO
COTOPAXI
GUALLABAMBA
PISQUE
IGUINARO
GUAM
CHINCHE
MACHANGA
PITA
SAN PEDRO
PROVINCIAL
STUDY AREA
CANTON
RIVER
0
10
KM.

Figure 10

(Basile, 1964: 24). Such features tend to divide the basin and the wheat producing area into many sub-basins.[8] This division, accompanied by pronounced relief, tends to limit the use of agricultural machinery because of difficulties encountered when moving machinery from one area to another.

The slope of the land affects the possible degree of agricultural mechanization within the study area. The slope of the wheat fields in the three cantons varies from zero to twenty-nine degrees, with a mean angle of inclination of 10.08 degrees. This is somewhat misleading, however, since a majority of the producers are located on fields of ten degrees or less. Figure 11 shows that ninety-six of 140 wheat producers have wheat fields of less than ten degrees with the majority of these having slopes between three and eight degrees. Of the remaining forty-four wheat fields, the majority are between sixteen and twenty-two degrees of slope. Five producers have wheat field slopes of twenty-four degrees, and there is one producer each on slopes of twenty-five, twenty-six, and twenty-nine degrees.

These slopes and the dissected terrain present a great problem to farmers who wish to mechanize. The use of large and complex machinery is problematic on steep slopes due to the possibility of overturning. Other important factors to be considered in the individual decision of whether or not to mechanize farming are higher repair and

8 The major sub-basins are Cayambe, Guallabamba, Tumbaco, Turubamba, Chillos, and Machachi sub-basins.

Wheat Field Slopes

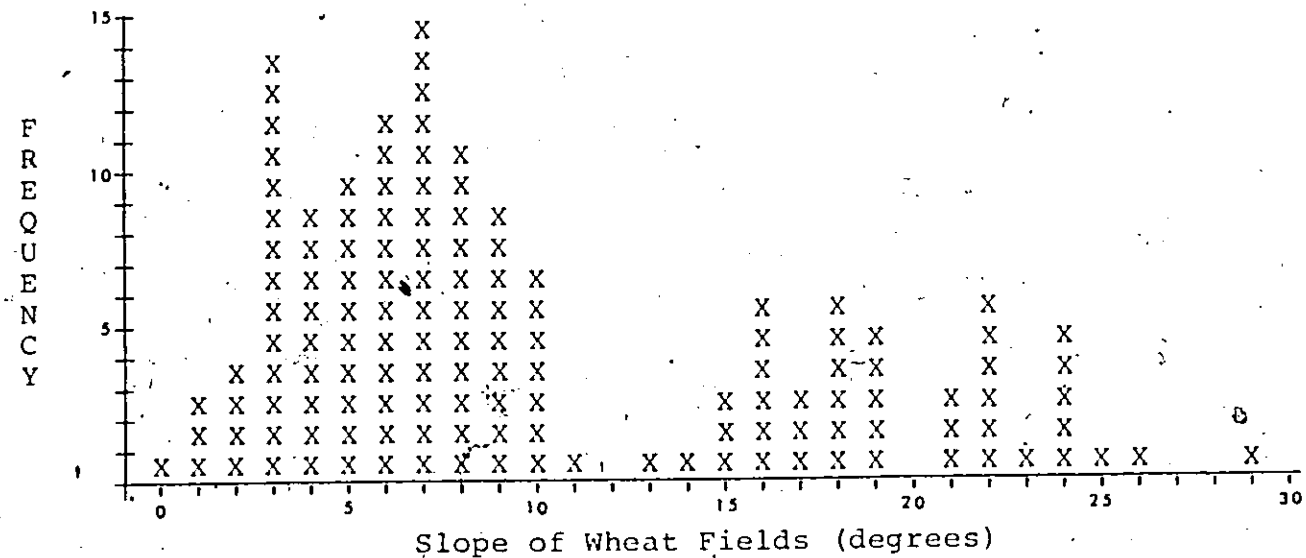

Figure 11

fuel costs due to the rough and steep topography of many parts of the study area. The alternative is of course the adaptation of machinery for use in the irregular and steep areas, but this entails a much greater investment by the farmer who is often unsure of mechanization in the first instance (Lee, 1957: 157).

An additional topographic problem is the altitude. Wheat farms varied from an altitude of 2,000 meters to 3,200 meters. Figure 12 graphically illustrates the distribution of the various farm altitudes within the study area, with their respective farm centers used as a reference point. The majority are still located at the more traditional Ecuadorian wheat farming altitudinal level of 2,800 to 3,200 meters, where most of the flat land is found. A large amount of wheat is produced at altitudes formerly used exclusively for dairy and corn production. During the interviews many producers on many of the higher wheat fields stated that there was a definite loss of advertised tractor power. As well as consuming more fuel, this machinery has the additional problem of becoming inoperable at high altitudes; therefore, special engine adaptations or more powerful equipment is necessary, but again at an increased cost to the farmer.

Climatology

The wheat producing areas of the study area correspond roughly to what is termed _tierra fria_, a climate belt based on altitude (Eidt, 1968: 64; Linke, 1960: 10). This climate

Altitudes of Wheat Producing Farms in Cantons Mejia, Quito, and Ruminhaui

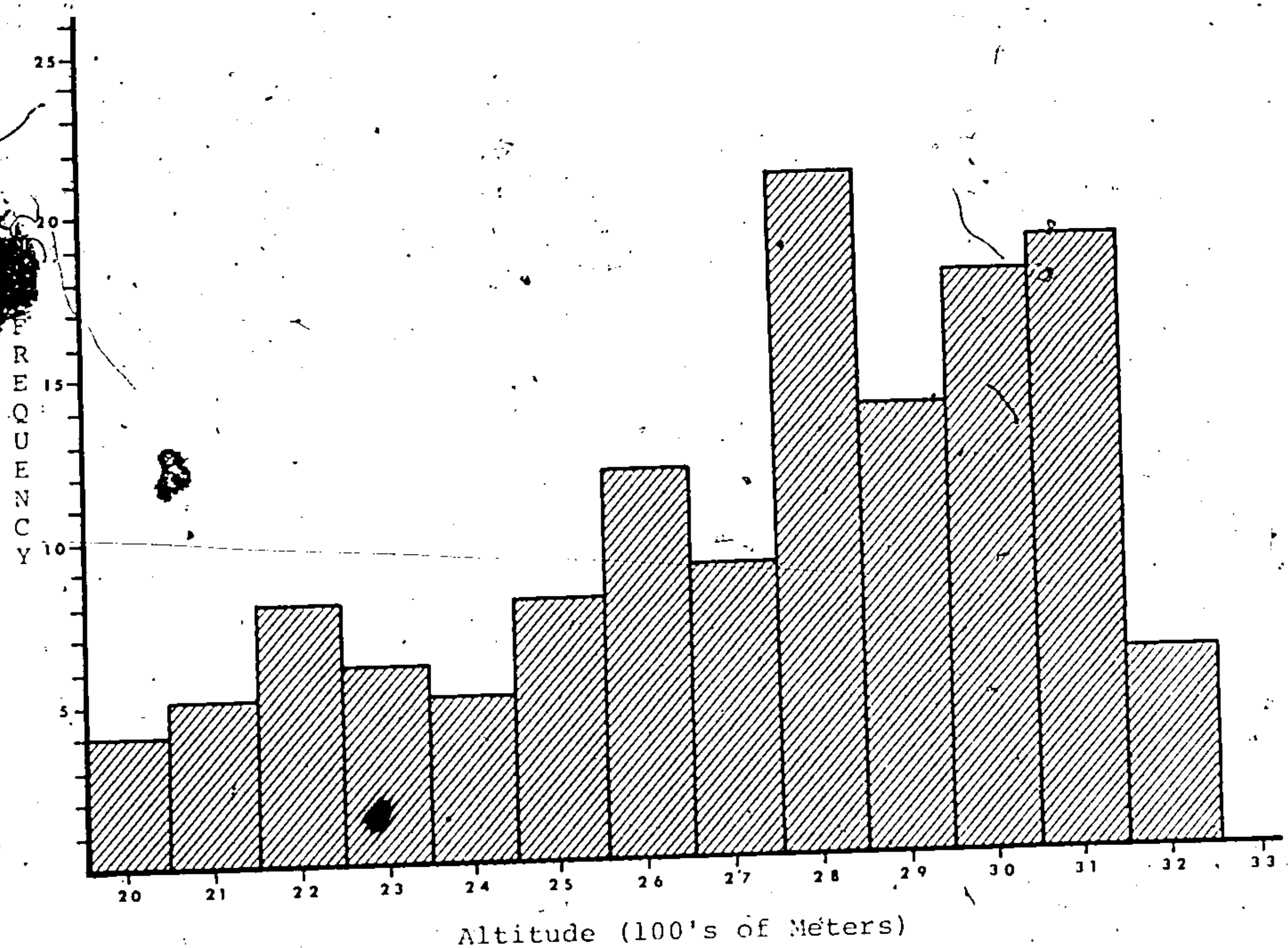

Figure 12

is found between the altitudes of 2,000 meters and 3,400 meters, with an average annual temperature range of twelve to eighteen degrees celcius; the annual temperature seldom varies more than 2.5 degrees celcius over small areas. For each increase in altitude of two hundred meters, there is a decrease in temperature of one degree celcius (Cordovez, 1961: 13). Because of this, altitude has perhaps the most significant effect upon the climatic characteristics of the study area. This fact, in consideration with slope and exposure, results in a wide variety of climatic situations (microclimates) which affect both wheat production and machinery use in a variety of ways.

With reference to Koppen's climatic system, the wheat producing areas of Pichincha Province include the lower altitudes of the ETI climatic region and the entire Cwb climatic region (Figure 13).

The ETI climate is characterized by a cool to cold (average 10°C) humid climate with a small annual temperature range. The wetness of this area, plus the altitude of over 3,000 meters, hinders the use of agricultural machinery. In many cases it is the small farms which are often located in these areas that are most influenced by this problem, but it is not solely limited to one or the other.

The Cwb climate is located at an altitude of 2,000 to 3,000 meters with a ten to fifteen degree celcius temperature, and five hundred millimeters of annual rainfall. The winters are usually dry in this climate, while the summers

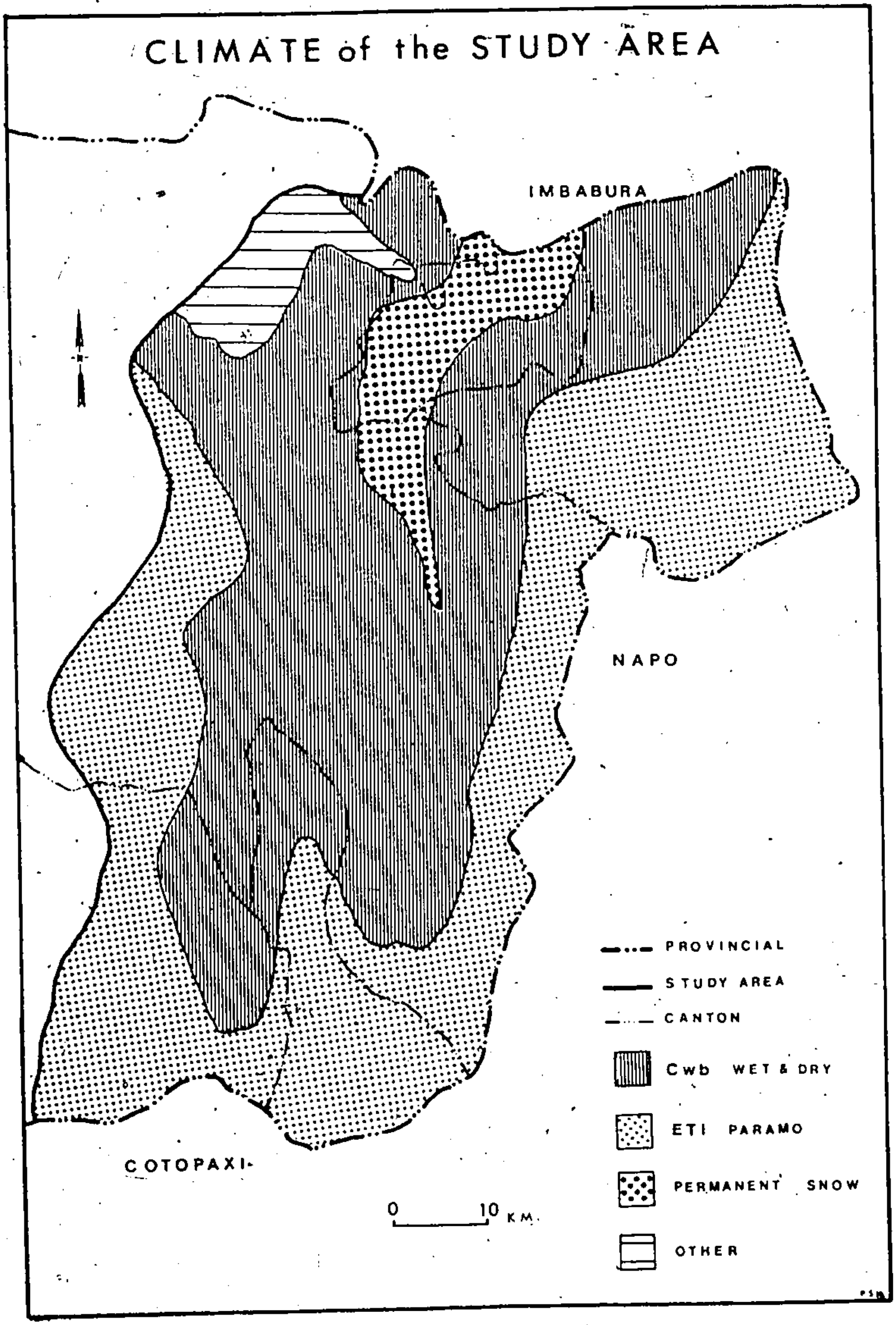
CLIMATE of the STUDY AREA
IMBABURA
NAPO
COTOPAXI
PROVINCIAL
STUDY AREA
CANTON
Cwb WET & DRY
ETI PARAMO
PERMANENT SNOW
OTHER
0 10 KM

Figure 13

are warm. This climate imposes no restrictions upon agricultural mechanization in the study area (Basile, 1964: 38-229; Cevallos, 1958: 52-60; Eidt, 1968: 72; Lee, 1957: 17). Large farms predominate in this area, but again, all farm sizes are represented in the climatic area.

The wheat producing areas generally receive their rainfall between February and May, and between October and November, but this does vary somewhat within the study area (Money, 1968: 98). There are basically two seasons in the study area of Pichincha Province, wet and dry. The seeding operations are carried out between October and April, and the harvest is completed between July and September. The total growing time is six months, but the two rainy seasons often interfere with both the seeding and the harvesting, affecting yields of wheat and the use of machinery. Yields are affected because of crop loss when the harvest is temporarily or permanently halted due to adverse weather conditions. The use of agricultural machinery either at seeding or harvest time is also hindered when the fields are heavily laden with surface moisture.

Table 7 shows the monthly temperatures and precipitation rates for various centers within the wheat producing area. Figure 7 can be referred to to show the locations of these centers. The highest annual temperature range is only 2.2 degrees celcius at the town of Pintag; the majority of these locations have only a slight range in temperature. The driest months for all locations are July and August.

Table 7 Mean Monthly Temperature and Precipitation of Various Centers in Cantons Quito, Ruminhaui and Mejia

Center	Elevation		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Var
Chillogallo	3,010	T	11.4	11.3	11.4	11.9	11.9	11.9	11.6	11.6	12.1	11.4	11.5	11.2	.9°C
		P	115.7	137.6	214.6	203.0	187.3	84.2	23.9	51.4	88.0	135.8	75.4	150.9	
		Y	5	5	5	5	4	4	4	4	4	4	4	4	
Machachi	2,950	T	14.4	12.6	12.6	12.8	13.1	12.7	12.6	13.3	13.6	14.1	14.4	14.4	1.8
		P	61.5	103.4	133.2	121.9	70.6	39.6	5.5	45.4	25.8	57.4	35.8	43.8	
		Y	2	3	3	3	3	2	1	2	1	3	2	2	
Pintag	2,900	T	13.2	13.3	13.0	13.7	13.7	14.9	15.2	15.0	13.7	13.0	13.0	13.2	2.2
		P	60.5	174.2	175.7	157.7	161.8	59.7	11.6	35.7	132.6	89.6	116.6	122.6	
		Y	5	5	5	5	5	3	2	2	1	4	5	5	
Sangolqui	2,518	T	15.9	15.7	15.1	14.7	14.4	14.1	14.9	14.7	15.0	15.9	15.5	16.1	2.0
		P	131.0	135.0	273.6	166.0	109.5	43.2	20.1	28.1	91.7	171.1	95.4	228.6	
		Y	3	4	4	4	5	5	4	3	2	2	2	3	
San Jose De Minas	2,780	T	15.6	15.4	15.4	15.5	15.1	15.4	16.2	16.4	15.9	15.5	15.6	15.7	1.2
		P	102.3	122.3	115.7	94.0	116.0	56.6	0.0	27.1	106.6	88.0	71.0	121.9	
		Y	5	5	5	4	4	2	1	1	3	3	4	4	
Uyumbicho	2,780	T	14.8	15.2	15.0	15.0	15.0	14.5	14.8	15.3	15.2	14.8	14.9	15.1	0.8
		P	176.4	161.5	183.3	196.7	201.1	89.6	49.4	15.0	107.8	90.4	76.5	107.3	
		Y	8	7	5	7	6	8	7	4	4	9	9	9	
Pifo	2,580	T	14.5	14.4	14.4	14.3	15.1	14.6	14.2	14.4	14.1	14.4	14.2	14.8	1.0
		P	88.5	19.9	116.3	48.0	99.5	46.0	7.5	0.0	28.4	43.8	19.6	26.0	
		Y	1	1	1	1	2	1	1	1	1	1	1	1	
Puellaro	2,000	T	17.8	18.2	17.8	18.3	17.9	18.0	18.5	18.1	18.2	18.1	18.6	18.3	0.8
		P	29.0	21.8	57.5	44.3	46.4	18.6	2.9	5.5	25.2	34.2	29.1	39.8	
		Y	9	9	9	9	9	8	3	7	7	8	10	10	
El Quinche	2,630	T	14.6	14.7	14.5	14.6	15.1	14.8	15.1	15.8	15.6	15.5	15.5	14.9	1.3
		P	104.5	58.3	101.2	114.4	69.8	39.0	11.7	3.8	37.4	62.4	38.5	49.3	
		Y	4	4	4	3	4	4	1	2	1	2	2	3	

1. T=temperature in °C.
2. P=precipitation in mm.
3. Y=years of observation.

(Source: Cordevez, 1961: 73-7)

The climatic conditions of the study area affect the possible use of agricultural machinery and wheat yields. The short harvest season may necessitate the use of machinery to expedite operations, when large amounts of labor are not available. In the case of seeding, the tractor can accomplish in a few hours what may have taken much longer by hand, and possibly could have been interrupted by rainfall when only partially completed. This would possibly make the harvest late and cause losses in yields due to adverse climatic conditions. Machinery may therefore alleviate some of the difficulties caused by climate affecting wheat cultivation.

Soils and Vegetation

The predominant soils of the wheat producing areas, all of which are volcanically derived, are the black paramo, moist sierran, and dry sierran varieties (Figure 14). The paramo soils are naturally unproductive on the average, but wheat is produced in its lower altitudinal extremities, and with the aid of fertilization, yields are sufficiently profitable. The parent material of the black paramo soil is volcanic ash combined with some heavy clays of glacial origin. This soil type is found between 3,200 and 4,000 meters in elevation. In the wheat producing areas of this soil belt the soil averages a temperature of eleven degrees celcius, while receiving one hundred millimeters of rainfall annually (Beek, 1968: 104; Basile, 1964: 90; Miller, 1959: 194).

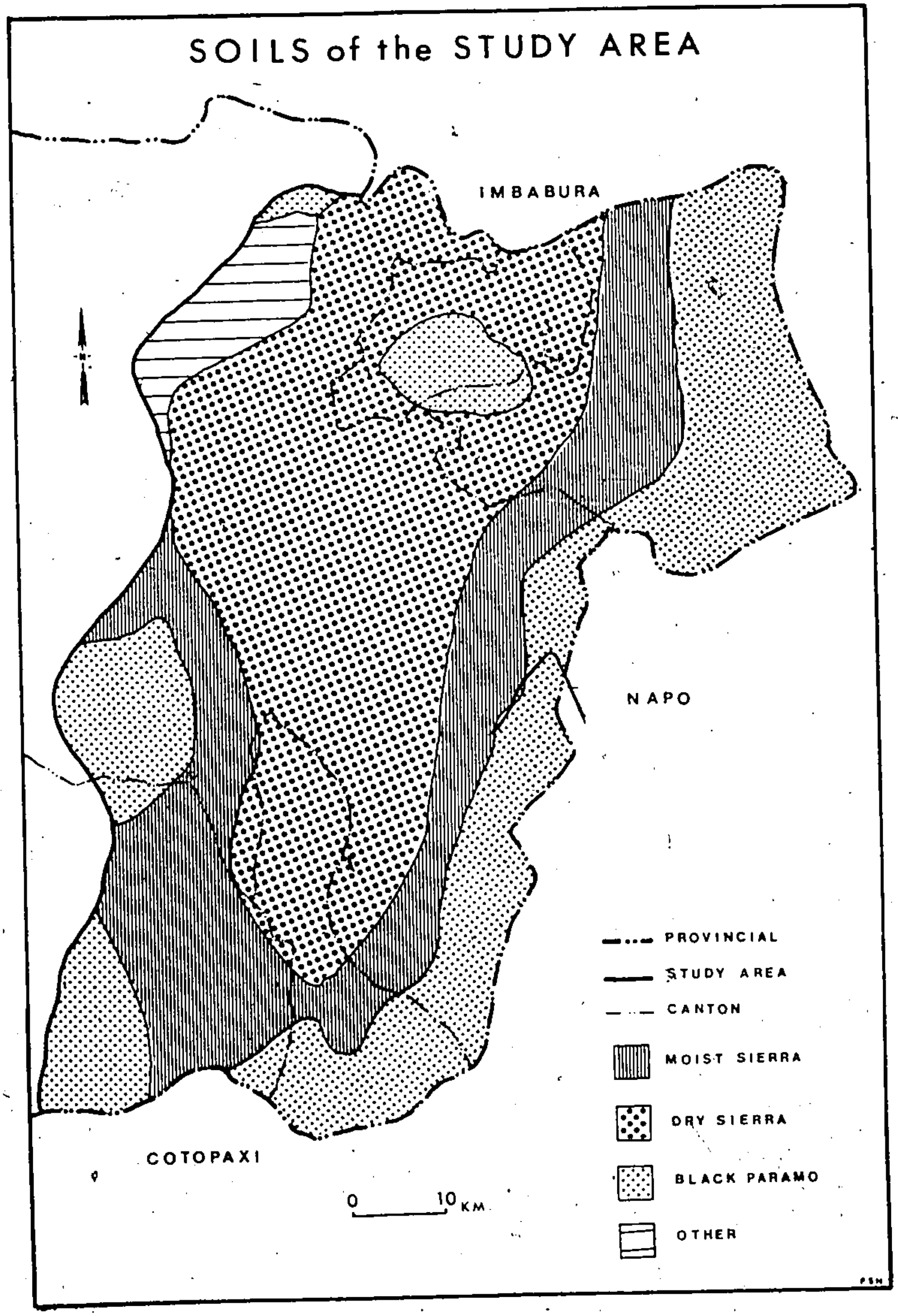
SOILS of the STUDY AREA
IMBABURA
NAPO
COTOPAXI
PROVINCIAL
STUDY AREA
CANTON
MOIST SIERRA
DRY SIERRA
BLACK PARAMO
OTHER
0
10 KM

Figure 14

The moist sierran soil has an altitudinal range of 2,500 meters to 3,200 meters; the main wheat producing areas are found in this soil zone. The temperature is slightly warmer than the black paramo, with an average temperature of thirteen degrees celcius. The soil is generally much more naturally fertile than the paramo variety. It receives between 100 and 150 millimeters of precipitation annually and has a well developed topsoil layer. Like the black paramo soil, the parent material of the moist sierran soil is volcanic ash (Basile, 1964: 90; Miller, 1959: 195).

The dry sierran soil group is found at an altitude range of 2,000 meters to 2,500 meters in elevation. The soil temperature varies from twelve to nineteen degrees celcius, and receives precipitation anywhere from twenty-five to one hundred millimeters annually. Like the previous two soil groups, the parent material of the dry sierran soil group is volcanic ash, with a texture varying from desertic sands to granular form in composition. Wheat production in this soil belt is usually confined to the upper altitudinal areas where precipitation is somewhat greater and soil temperatures are lower (Basile, 1964: 90; Beek, 1968: 104; Miller, 1959: 195).

The natural vegetation associated with these three types of soils is bunch grass in the black paramo soil group, bush forest in the moist sierran, and xerophytic brush and grass in the dry sierran areas. In general, the vegetation of this area is strictly controlled by altitudinal levels, but much depends upon local soil and climate. In many parts of the study area microclimates cause rapid changes in both soil and vegetation over short distances (Beek, 1968: 104; Cordovez, 1961: 17; Money, 1968: 93). In general the soils of the wheat producing areas are dark, very moist, and cool acidic in reaction. Fertility is higher than in the average tropical soil but without crop rotation and fertilization, wheat yields would still be low in quantity.

These soils have various effects on the use of agricultural machinery in the study area. One effect of the black paramo and moist sierran soils is that the clays of glacial origin which are present in both soils to some degree, combined with heavy soil moisture, often make machinery less efficient than it should be. This soil characteristic, combined with lost machinery power due to altitude, poses a serious problem to the mechanization of agriculture in this area. The dry sierran soil areas are often greatly dissected by erosion cutting wheat fields into small sizes, causing inefficient maneuverability of machinery (Cordovez, 1961: 17-20). Most agricultural machinery used in this area was designed for use in temperate areas and on flat fields (Tempany, 1958: 132). A final effect is that rapid changes in soil groups may necessitate different machinery applications. For example, fertilizer formula may have to be changed mid-field as soil types change, rendering machinery use less efficient. Also, different types of plows may have to be used when preparing the soil with machinery in the mosit and dry sierran soil areas. Soil variation on individual farms is mainly a problem for the large producer; this is not always the case, however, because some small producers also encounter this problem.

The soils of an area can possibly affect the rate or level to which agricultural machinery can be used for farming. In reference to the four hypotheses, the soils of the study area would seem to generally affect the possible level of mechanization and the yields of wheat as topography and climate do. Problems caused by variations in the type of soils could be remedied by special machinery adaptations, but again, this would have to be done at a much higher cost to the wheat producers.

Agricultural Influences in the Study Area

The agricultural characteristics of the study area are of great importance in the discussion of agricultural mechanization, as they can influence the level of mechanization, either directly or indirectly. Farm field size can have a direct influence upon mechanization levels in terms of the need for sufficient areas under cultivation to make machinery use efficient. The education, technical training, and wages paid to the agricultural labor force, as well as distance from machinery service centers, are indirect considerations in any discussion of agricultural mechanization. The quality of the extension services offered to agriculturalists and the availability of credit to purchase machinery could have a direct influence upon an area's degree of mechanization, as well as on the use of other modern practices or inputs. It is therefore necessary to discuss these factors and their influence upon mechanization, and this will be attempted as much as possible within the context of the study area alone.

Figure 15 shows by cantons the total number of hectares farmed by the three cantons' wheat producers, the amount of this under wheat cultivation, and the amount used for other crops. In terms of total hectares or farm size of the wheat producers, Canton Quito has the largest wheat area, with 15,157 hectares. The majority of this land (11,722 hectares) is used for the cultivation of crops other than wheat; in this canton wheat is only cultivated on 877 hectares of the total land. Slightly more than 3,000 hectares of the wheat producers' land in this canton is either too steep or too high, or is used for purposes other than crop cultivation. In Canton Mejia wheat producers' land totals 9,606 hectares, and of this 1,346 hectares are used to cultivate wheat, a substantially greater amount than in Canton Quito. In Canton Mejia 4,923 hectares are used for crops other than wheat, while 3,337 hectares are either used for other purposes, or are unsuitable for agriculture or improved pasture. In relative comparison there is a greater amount of land used for other purposes in this canton than in Canton Quito. In Canton Ruminahui there are only four wheat producers whose farms total 1,755 hectares, and only 110 hectares of this is used for wheat cultivation. A further 1,595 hectares are used for crops other than wheat, while only fifty hectares

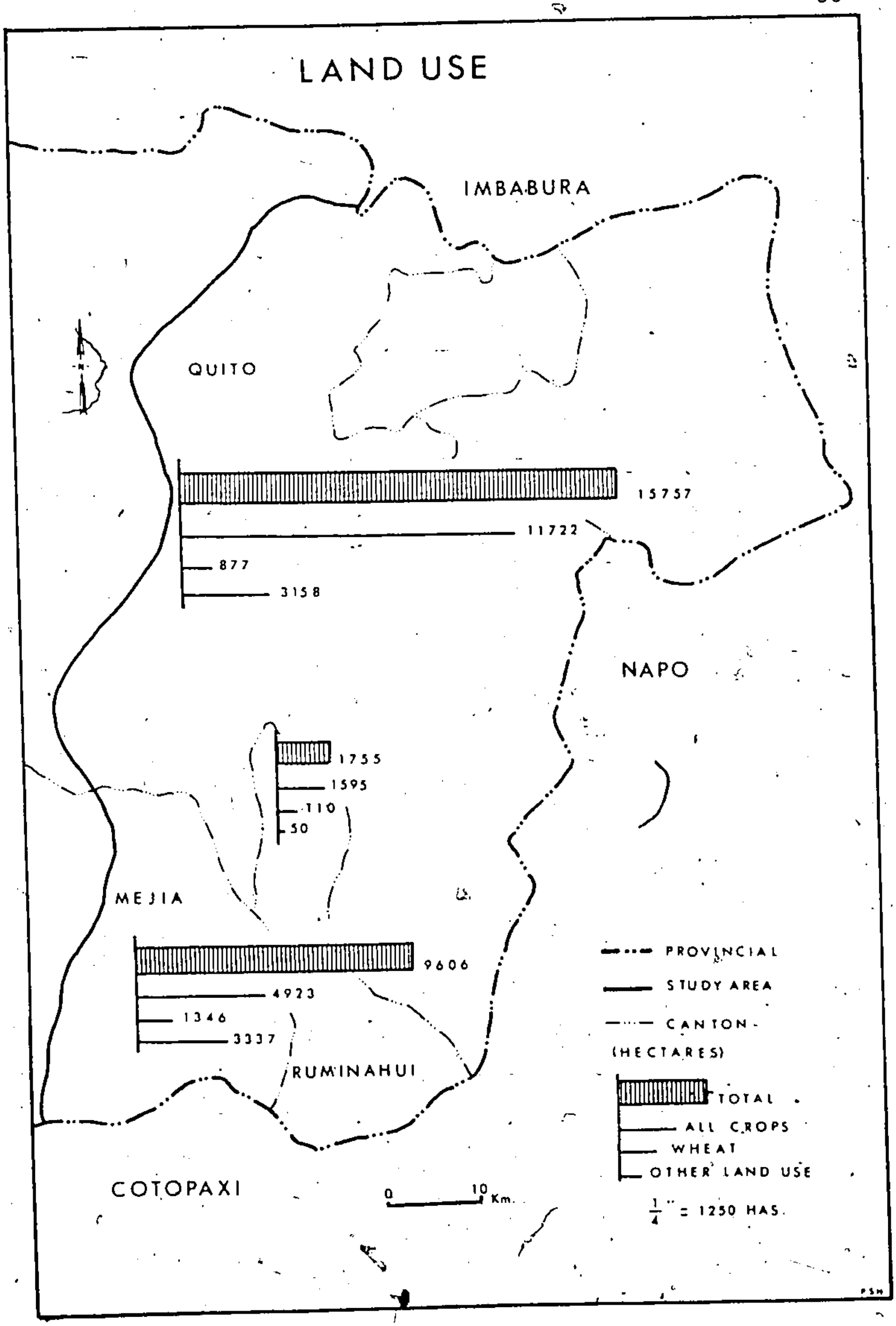
LAND USE
IMBABURA
QUITO
15757
11722
877
3158
NAPO
1755
1595
110
50
MEJIA
9606
4923
1346
3337
RUMINAHUI
PROVINCIAL
STUDY AREA
CANTON
(HECTARES)
TOTAL
ALL CROPS
WHEAT
OTHER LAND USE
1/4" = 1250 HAS.
COTOPAXI
0
10
Km.

Figure 15

are unused.

Figure 16 shows the total number of producers by nine farm size categories chosen for this study. The majority of these wheat producers (32) have farms of less than five hectares, while there are thirty producers in the 100 to 199.9 hectare size category. Farms of 5 to 9.9 hectares and 200 to 499.9 hectares form the third highest category with each size range having seventeen producers in it. In total there are a greater number of farms less than ten hectares than there are between the wider spaced categories of 100 to 499.9 hectares.

The actual amount of land under wheat cultivation has a greater influence upon agricultural mechanization than does the actual farm size, and generally the proportion seeded in wheat within the study area is far less than the total number of hectares of the farms. While figure 16 shows the actual size of the farms within the study area, figure 17 shows the areas of these farms which were planted in wheat. This study of machinery use is directly concerned with the size of these wheat fields.

In comparing these two figures we see that there are twice as many farmers cultivating less than five hectares of wheat than there are farms of this size category. Seventy-five of the total 140 wheat producers cultivate less than five hectares of wheat. Of the remaining sixty-five wheat producers, twenty-one utilize twenty to 49.9 hectares, eighteen use between ten and 19.9, and only three utilize

Farm Size of Wheat Producers (hectares)

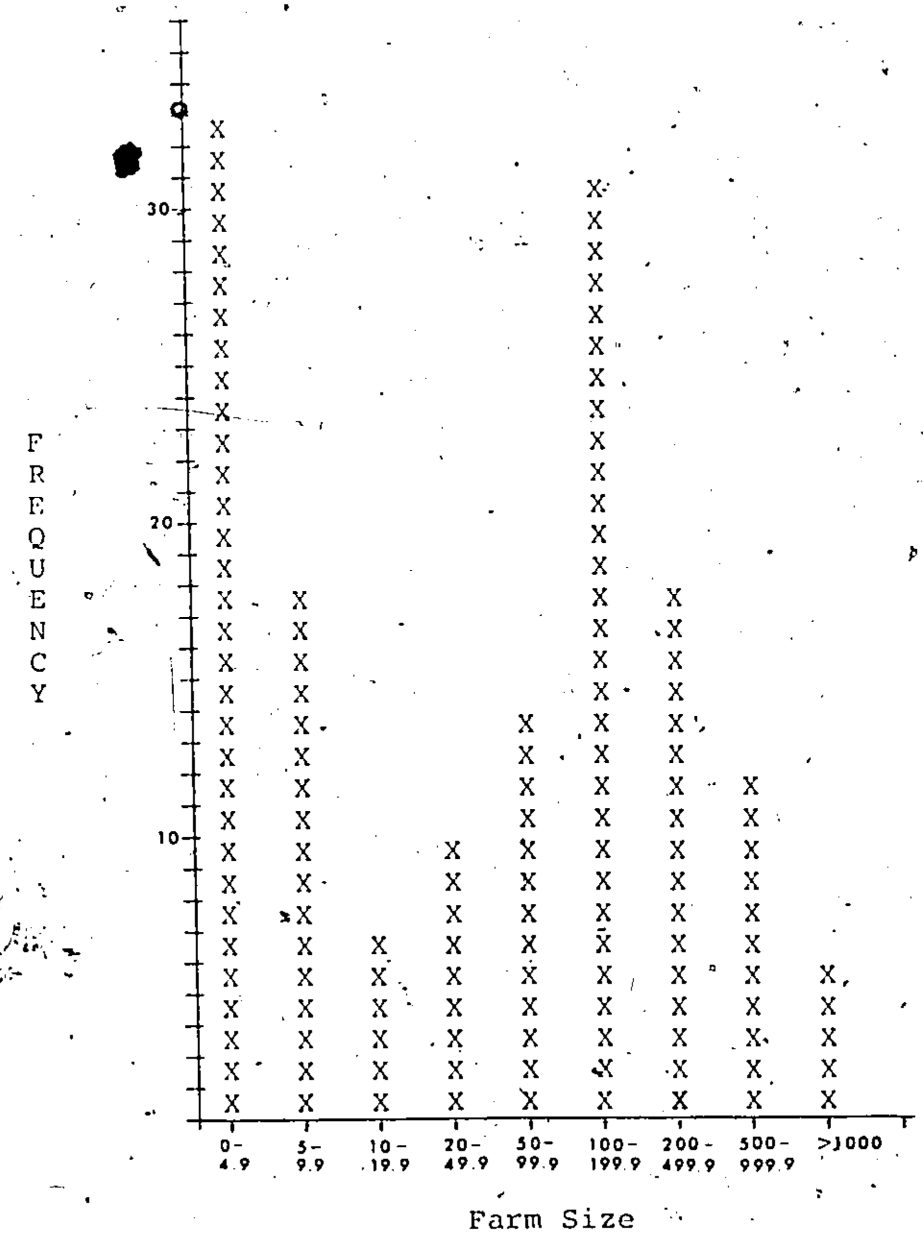

Figure 16

Hectares of Wheat Under Cultivation

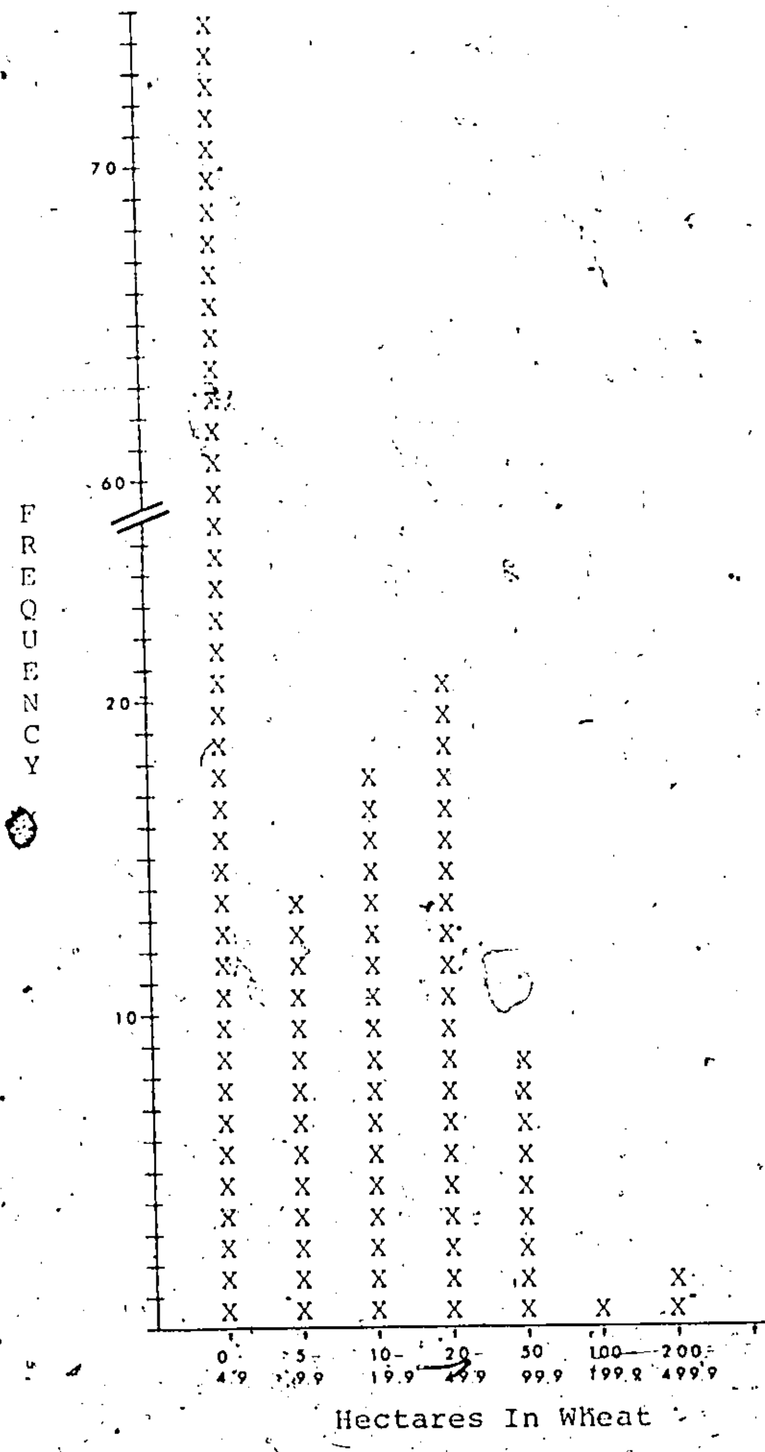

Figure 17

more than one hundred hectares of their farms for wheat cultivation. One of these three uses 320 hectares for wheat production, which is the maximum area utilized by one producer within the study area. The mean number of hectares under wheat cultivation in the whole area is 16.49 hectares.

As farm size increases, so does the level of mechanization. Of the wheat producers with less than five hectares, 81.3% use no machinery at all (Table 8). All but two producers that grow more than twenty hectares of wheat use some mechanization. In total, thirty-eight of the forty-five producers not using machinery are farmers having less than ten hectares of property, while twenty-five of the thirty-one fully mechanized producers have properties greater than one hundred hectares.

The level of mechanization for the small farmers is not a product of size alone, although this factor tends to be a dominant one. Mechanization is difficult on small farms due to difficulties in maneuvering the machines on small plots of land. Mention must also be made of the situation where many of the small wheat producers in the study area are also located on steep slopes, but this will be discussed later. The conclusion, therefore, is that small farm size, at least in part, could influence the level of agricultural mechanization within the study area.

Agricultural Population

There are certain characteristics of the agricultural

Table 8 Level of Mechanization of Farms in Cantons Mejia, Quito and Ruminhaui By Farm Size

Size(HAS)	# of Farms	Fullmech		Partialmech		Nomech		Total
		#	%	#	%	%	#	
0- 4.9	32	0	0.0	6	18.7	26	81.3	100
5- 9.9	17	1	5.8	4	23.5	12	70.7	100
10- 19.9	6	0	0.0	1	16.6	5	83.4	100
20- 49.9	9	2	22.2	7	77.8	0	0.0	100
50- 99.9	13	3	23.0	9	69.4	1	7.6	100
100-199.9	30	8	26.6	21	70.1	1	3.3	100
200-499.9	17	9	53.0	8	47.0	0	0.0	100
500-999.9	11	5	45.5	6	54.5	0	0.0	100
1000	5	3	60.0	2	40.0	0	0.0	100
Total	140	31	----	64	----	45	----	---

population which could influence the level of farm mechanization. The first of these considerations is wages paid to the agricultural labor force within the study area. The prevalent wage for an agricultural worker is one dollar (U.S.) per hectare for seeding by the broadcast method (Programa, 1973: n.p.). This wage would be exclusive of a noon time meal in most of the study area. The standard wage for manual wheat harvesting in the area is only fifty cents per hectare. With these low wages it is unprofitable in many instances to purchase more machinery than a tractor, even in areas capable of being easily mechanized. Therefore wages would tend to influence the level of mechanization in the three cantons under study.

Another human characteristic which could influence the level of mechanization within the study area would be the level of education among the wheat producers. In a 1964 study of agricultural development in Ecuador the International Committee of Agricultural Development (1964: 30) stated,

> One of the most important requirements for a progressive agriculture is that virtually all members of the farm population be able to read and write. Otherwise the farm population cannot benefit from the printed material on modern technology, or arrive at a concensus as to their needs and make them known to the government.

In the 1962 Ecuadorian national census 30.6 per cent of the population over six was literate. No indications were given as to the literacy rates of the rural population, but they are thought to be considerably below the national levels, and levels within the study area are not drastically different from those within the nation as a whole (Comite, 1964: 30). Much of the information given to farmers within the study area is in the form of written literature such as the costs and benefits under two levels of farm mechanization, depicted in tables 5 and 6. It is also difficult for a producer with little education to readily accept new ideas or innovations (Coolman, 1960: 270). The level of agriculturalists' education can therefore affect the study area's degree of agricultural mechanization.

The final characteristic of the agricultural population which influences mechanization within the study area is the availability of trained personnel to operate the machinery and make repairs as the need arises. This consideration is highly associated with the previous one, namely, education levels. There is a general lag in the progress of mechanization until the labor force can be adequately trained to operate and repair increasingly complex agricultural machinery (Mellor, 1954: 105).

In 1954 there was only one tractor for every 3,500 hectares of agricultural land in Ecuador (Nisbet, 1966: 168). This situation has changed somewhat, and in 1968 there was one tractor for every 2,400 hectares; of those, ninety-five per cent (2,544) were in the private sector (Junta, 1971: 61; Programa, 1973: n.p.). The training of personnel to repair machinery has been relatively neglected by the machinery distributors. Not only has this led to problems for current agricultural machinery users, but it has also created a reluctance by other wheat producers in the study area to mechanize their farming. In reference to this situation, the government is reluctant to interfere with private enterprise (Programa, 1973: n.p.).

Service Centers

The road distances between the farms and the various service centers which serve them are of importance in the use of agricultural machinery. This is true in terms of fuel services, preventive maintenance servicing, and general repairs. The distances between the area's farms and the nearest town, canton capital, and the area's largest city, Quito, were calculated for each of the area's wheat producers.

Figure 18 shows the distances between the individual farms and their nearest town. These centers would have fuel services and a low degree of preventive maintenance facilities. The mean distance to the nearest town was 4.24 kilometers. The actual situation can best be seen by considering the range of zero to twenty kilometers to the nearest town. This figure shows that all but twenty of the area's 140 wheat producers are within six kilometers of the nearest town. Most of the farms located further away are on steep valley sides above their closest town.

Distances From Farms To Nearest Town

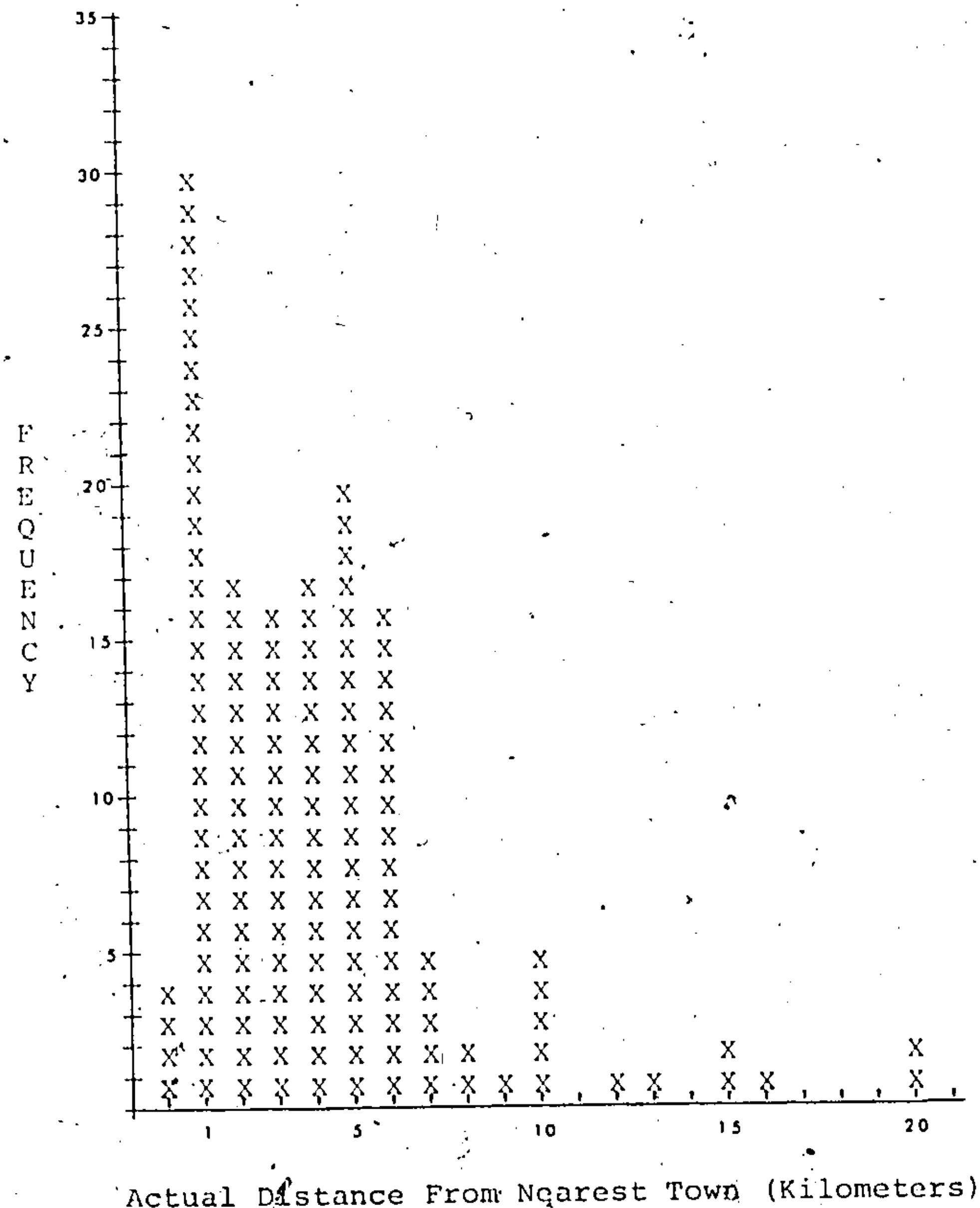

Figure 18

In the same manner figure 19 shows the distances from the individual farms to their respective canton capitals of Machachi, Sangolqui, and Quito. The mean distance from the study area's farms to their canton capitals is 19.39 kilometers, while the range is from a minimum of two kilometers to a maximum of fifty-six kilometers. Figure 19 shows that a large number (68) of the area's wheat producers are within ten kilometers of their respective canton capitals, but there are nearly as many who are beyond twenty-five kilometers from these centers. Twenty-four of these are beyond forty-five kilometers from their canton capitals. It is felt that the best distance in terms of obtaining mechanical services is ten to twenty kilometers (Programa, 1973: n.p.).

Figure 20 shows the distances of the area's wheat producers to Quito, the area's largest center. Quito provides even more specialized mechanical services and it is also the central supply depot for agricultural machinery parts. Specialized repair services such as transmission repairs would normally take place in Quito. The mean distance of wheat producers from Quito is 26.93 kilometers with a standard deviation of 15.04 kilometers. The distance of these wheat producers ranges from four kilometers to fifty-six kilometers. Figure 20 shows that while there is a considerable number (31) of producers ten kilometers or less from Quito, the majority are more than twenty-five kilometers away from this center. Thirty-six farms are twenty-six to thirty kilometers away from Quito, and twenty-three farms are

Distance From Wheat Farms to Canton Capitals

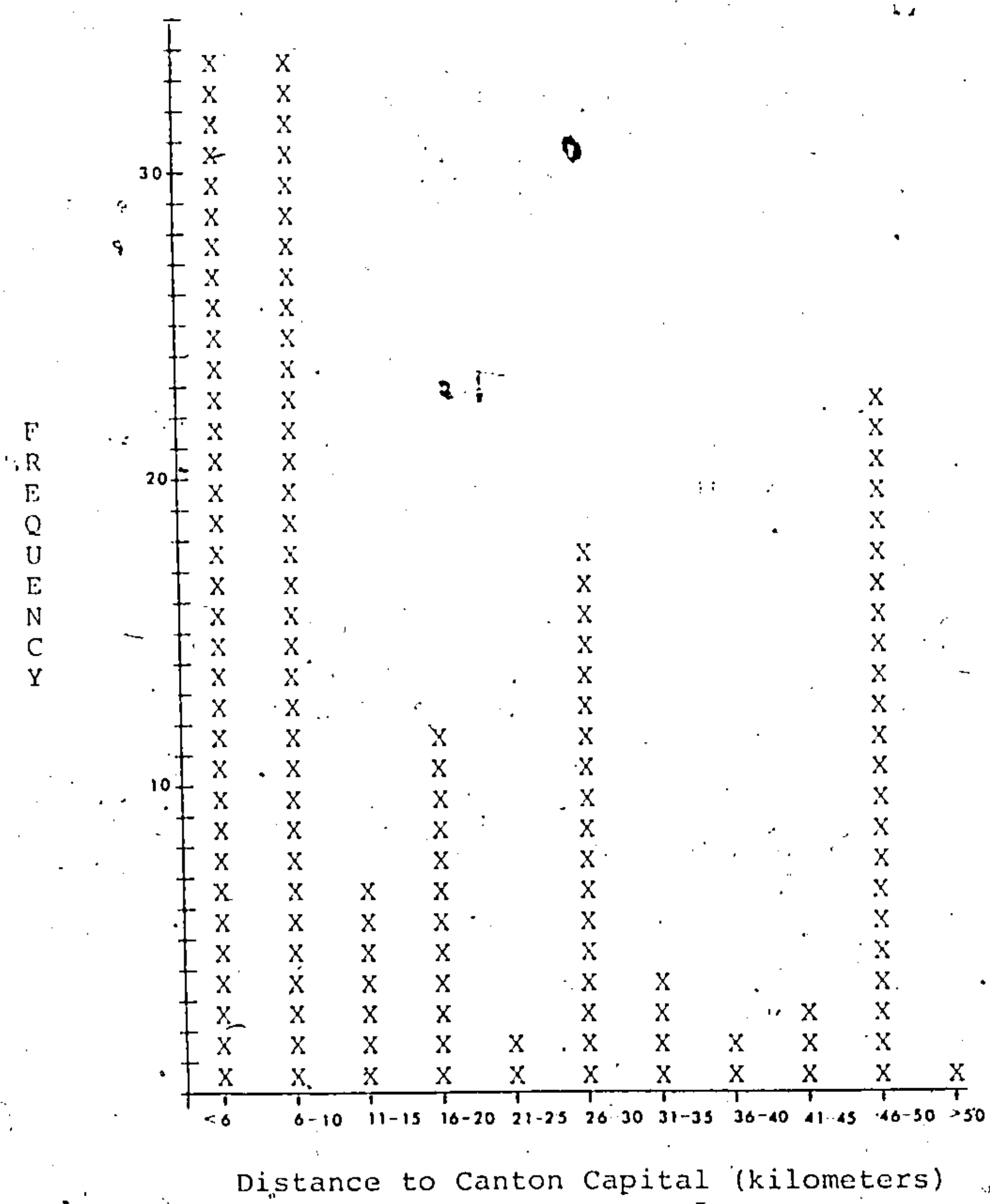

Figure 19

Distance From Wheat Producers' Farms to Quito

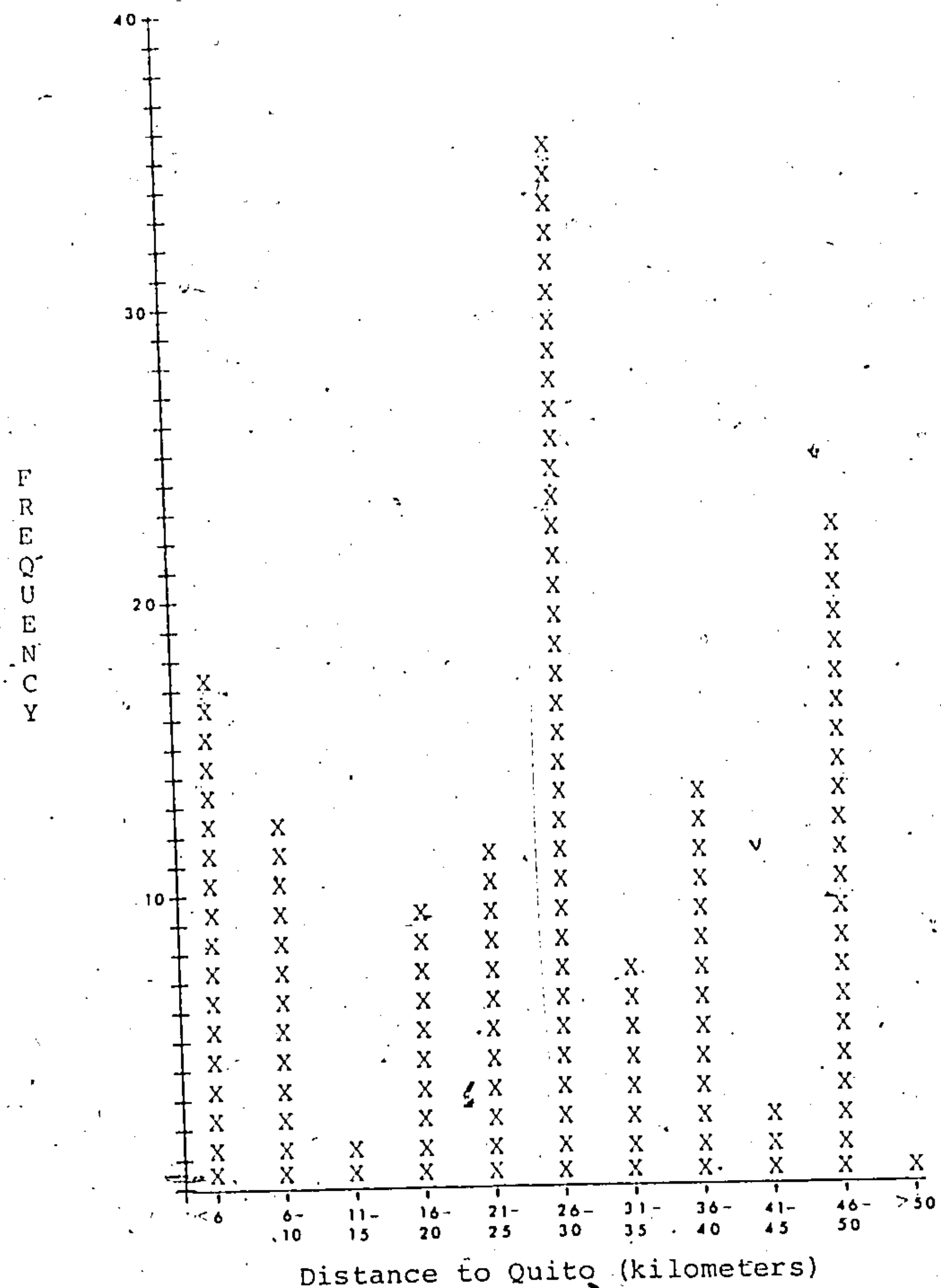

Figure 20

forty-six to fifty kilometers from Quito

The distance which machinery users must transport their equipment for servicing or repairs would tend to affect the efficient use of it in any area. In the study area, decisions to mechanize holdings would seem to depend upon the proximity of these facilities to the farms in question, as it would in other areas.

Agricultural Extension

Agricultural extension work is of the greatest importance in the diffusion of information on recent modern agricultural practices. This is true not only in the case of agricultural mechanization, but also in the use of other modern agricultural inputs and practices within a farming system. The purpose here is to review agricultural extension work within the three study cantons in the primary context of machinery use, and also in terms of the use of other modern inputs and practices.

There is no one agency in Ecuador which is responsible for extension work; these activities are conducted by a number of organizations. However, at present most extension work is centered and coordinated by one agency, the _Servicio Nacional de Extencion Agropecario_. In wheat production, therefore, there is a duplication of services by the _Programa Nacional de Granos_ (Comite, 1965: 62; Programa, 1973: n.p.).

Within the study area there exist basic problems associated with agricultural extension which are by no means local. Besides the duplication of services to wheat producers, there is a lack of well trained extension workers, and a lack of transportation for them. This has resulted in the extensionistas visiting and providing relevant information only to those wheat producers who are situated close to the main transportation networks because of heavy work loads and lack of vehicles.

In many instances the extension workers only visit the large wheat producers, although this group of producers have other means of obtaining the same information. This situation is partially caused by cultural differences in the society as a whole, and also because most of the larger producers are located near main transport networks within the study area. The small farmer who needs the advice most is often neglected by this agricultural service.

There is a need not only for improved means of reaching all wheat producers, but also a need for improved means of convincing farmers of the usefulness of improving their farming practices as much as possible.

The mode of presentation by extension workers is of the utmost importance. Research teams from the National Research Institute working in conjunction with extension workers are now selecting various fields for wheat test plots, using better seed, better soil preparation and fertilizer application. These test plots have tended to have an impression upon the area's wheat producers, especially upon the small-farmer (Programa, 1973: n.p.). The producer can see the results obtained on his neighbor's land and can easily be convinced that he should try the introduced practices himself (Comite, 1964: 48-50; Comite, 1965: 59-76; Lee, 1957: 51-52).

As a result of recent work by both research teams and extension workers, most of the wheat producers in the study area are now aware of recent technologies in wheat production, but vehicles and well trained personnel must be provided for personal interviews with all of the producers if wheat production is to increase.

Butland (1960: 187) stated, "In the Sierra the traditionalism and primitive and inefficient methods of grain production seem almost incapable of change." The signs of change are in evidence now as more producers adopt methods of increasing their output (Money, 1968: 99). There is still need, however, for expansion in the use of machanization, crop rotation, fertilizer, and other improved methods of soil management (Cordovez, 1961: 37; Gore, 1971: 7; Himebough, 1966: 41; Italconsult, 1963: 135).

Table 9 depicts the total use of fertilizer in Ecuador from 1955 to 1969. There has been a general increase in its use, which at least partially reflects the work of the extension workers throughout the country. In 1965 the first domestic producer of fertilizer was established, enabling greater amounts of fertilizer to be used. By 1969 domestic production of fertilizer had satisfied demand for this agri-

Table 9 Total Use of Fertilizer in Ecuador From Foreign Imports and Domestic Production

Year	Imports[1]	%Increase	Domestic Production[1]	%Increase	Total
1955	7,857	2			7,857
1956	8,885	13			8,885
1957	13,249	49			13,249
1958	12,374	-7			12,374
1959	14,293	16			14,293
1960	15,667	10			15,667
1961	14,182	-10			14,182
1962	11,991	-18			11,991
1963	18,974	58			18,974
1964	29,034	53			29,034
1965	31,568	9	16,000		47,568
1966	28,926	-9	24,257	52	53,183
1967			39,257	63	39,257
1968			40,261	2	40,261
1969			48,000	19	48,000

[1] Metric tons

(Source: Gore, 1971: 12)

cultural input.[9] Domestic production 1973 was however, unable to supply demand and importation had to be resorted to in order to make up the balance.

In a 1970 study of sierran wheat production, statistics were compiled on fertilizer use by the producers (Gore, 1971: 10). Table 10 shows the effects in terms of yields of various fertilizer applications. When fertilizer was correctly applied to wheat fields, the resulting yield was 11.1 quintals per hectare for every quintal of fertilizer used. When fertilizer was applied indiscriminately, the resulting yields decreased to 6.1 quintals per hectare, which was in fact a lower yield than those wheat fields having no fertilizer application. Gore found that only thirty-two per cent of the wheat producers in his study used the correct application of fertilizer; he felt that a thirty per cent increase in wheat production could be realized if fertilizer was correctly used.

Table 10 Fertilizer Application in the Ecuadorian Sierra and Resulting Yields Per Quintal of Fertilizer Applied.

Fertilizer Application	Yield (QQ/Ha)		Fert (QQ/Ha)	# of Cases
Correct application	11.1	:	1	58
Indiscriminate application	6.1	:	1	31
No application	7.3	:	0	92

(Source: Gore, 1971: 10).

9 Some advantages of the domestically produced fertilizer were that it had a lower price, it was of the same quality as imported fertilizers, it was better formulated for Ecuadorian conditions and soils, it could be provided in the necessary quantities at the necessary speed, its manufacture provided domestic employment, and it saved the use of foreign exchange (Gore, 1971: 11).

There is fairly widespread use of fertilizer within the three cantons under study. The mean amount of fertilizer used per hectare is 3.19 quintals, but because of the large number of non-users (23) the standard deviation is ±2.37 quintals per hectare. Again the range is more indicative of fertilizer use with a minimum of no (0) fertilizer being used to a maximum of fourteen quintals per hectare of wheat.

Table 11 shows the number of fertilizer users by the amounts they use for each size category of wheat-producing farm within the study area. The largest category of non-users of fertilizer are those producers with less than five hectares of total peoperty, where forty-seven per cent use no fertilizer whatsoever. The next highest non-users of fertilizer are those producers falling into the 100 to 199.9 farm size category, where seventeen per cent use no fertilizer. When considering relative numbers, this group also rates in terms of actual numbers as the largest user of fertilizer, because twenty-five of their thirty producers use some fertilizer. In total, there are only twenty-three of the 140 wheat producers within the study area who use no fertilizer at all; therefore, eighty-four per cent of this area's wheat producers employ fertilization in their wheat production.

Fertilizer is, however, often applied without consideration for the amount or formula used. Each soil type encountered in the wheat producing area needs a different amount of fertilizer with variations in formula (Cordovez,

Table 11 Fertilizer Used in Cantons Mejia, Ruminhaui and Quito By Amount Used By Size of Categories of Farms

Amount of Fertilizer Used (QQ/Ha)	Number of Users By Size of Farm (Hectares)									
	0-4.9	5-9.9	10-19.9	20-49.9	50-99.9	100-199.9	200-499.9	500-999.9	1000	Total
0	15	2	1	0	0	5	0	0	0	23
1	4	1	1	0	3	1	0	0	0	10
2	6	9	1	3	1	1	2	2	2	27
3	3	2	2	1	1	4	2	1	1	17
4	4	2	0	3	5	5	10	1	1	31
5	0	0	0	0	1	3	0	2	0	6
6	0	1	0	1	1	6	3	4	1	17
7	0	0	1	0	0	2	0	0	0	3
8	0	0	0	1	0	3	0	0	0	4
9	0	0	0	0	0	0	0	1	0	1
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	1	0	0	0	0	1
Total Users of Fertilizer	17	15	5	9	13	25	17	11	5	117
Total Farms In Size Group	32	17	6	9	13	30	17	11	5	140

1961: 37). Extension agents are attempting to correct this situation by having producers' field days at the Santa Catalina Research Station near Quito. Two plots are fertilized, one correctly and the other incorrectly. The results are easily seen by those in attendance, but again the greatest misuser of fertilizer, the small farmer, is often not present at the field day because he did not know about it (Programa, 1973: n.p.).

The extension service is significant in the manner in which they further the use of biological and mechanical inputs into the agriculture of the study area. Their work directly influences the level of mechanization possible, as well as wheat production in general. There must be an honest attempt to reach all producers within the study area. This modernization of agriculture is of course dependent upon the availability of agricultural credit, to which the discussion will now turn.

Agricultural Credit

Agricultural credit is one of the most important agricultural influences upon agricultural mechanization in the three study cantons. The lack of agricultural credit is recognized as being the major cause of the retarded growth of agricultural mechanization in Ecuador (Bottomley, 1966a: 63; Comite, 1965: 12; Gore, 1971: 12; Italconsult, 1963: 136). Available credit for machinery purchase has decreased in real terms since 1955, and in the first half of the

1960's the shortage of credit was acute for machinery purchase and for other agricultural production purposes as well (Gibson, 1971: 51; Italconsult, 1963: 438).

There are two basic kinds of credit markets for agricultural purposes in Ecuador, an institutional market and a non-institutional market (Stitzlein, 1967: 11). The institutional lenders of agricultural money are private banks and the Banco Nacional de Formento. The latter is operated by the Central Bank of Ecuador to provide agricultural credit. In 1972 this bank provided twenty-one million sucres[10] of credit to be used in the purchase of agricultural machinery in the Sierra (Programa, 1973: n.p.). This bank also provided a further twelve million sucres to be used for the purchase of biological commodities for use in wheat production on the national level. While eighty-five per cent of those seeking loans borrow money from this source, there still exist a great number of producers who are not aware of the relative ease of borrowing funds from the Central Bank. Some producers are not even aware of the Banco de Formento, which, as a credit source, charges a rate of interest between four and eight per cent on its loans (Segovia, 1965: 43; Stitzlein, 1967: 15).

Private Banks lend some funds for agricultural purposes, but the total amount is still small in reference to their other loans. Table 12 shows the destination of funds pro-

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10 25 sucres = 1 dollar (U.S. approximately).

vided by private banks in Ecuador. The flow of funds to agriculture is far less than flows to the other sectors of the economy. The percentage of private banking funds loaned for agricultural purposes in 1963 was only 3.4 per cent, while commerce and industry together received eighty-five per cent of this credit source's funds. Private banks charged between thirteen and eighteen per cent interest in 1967 (Stitzlein, 1967: 15).

Table 12 Credit Provided by Private Banks (1000's of Sucres)

Destination	1960	1961	1962	1963	1963%
Commerce	1,822,225	1,903,644	1,889,962	2,108,192	72.8
Industry	271,238	283,661	277,809	375,873	13.0
Agriculture	109,107	102,473	93,943	98,874	3.4
Other	376,415	351,562	250,989	312,019	10.8
Total	2,579,015	2,641,340	2,512,703	2,894,958	100.0

(Source, Segovia, 1965: 44)

The second main source of agricultural credit in Ecuador is the non-institutional credit market. For most lenders of this sort the occupation of lending money is a secondary one. An example of this type are local store owners who advance credit for purchases of agricultural inputs or home necessities until the harvest has been sold (Stitzlein, 1967: 17). For some of these lenders this occupation is their only source of income. Most users of non-institutional money are small farmers, due to their lack of collateral and the fact that they are often high risk borrowers. This is particularly true when considering renters of agricultural land or sharecroppers. In his study of the rural credit market in Ecuador, Stitzlein found that sixty-nine per cent of non-institutional credit users farmed areas of less than ten hectares (Stitzlein, 1967: 37).

Interest rates charged by the non-institutional lenders varied from zero to sixty per cent (Segovia, 1965: 43; Stitzlein, 1967: 29-34). In Stitzlein's study, sixty of 156 users paid twenty per cent interest, while forty-four paid from thirty to thirty-six per cent (1967: 34). In the latter case any additional productivity achieved by the farmer is lost to the higher interest he must pay for his agricultural loans (Bottomley, 1966a: 62). Furthermore, borrowers are obliged to repay their loans immediately after the harvest, and therefore must sell to a glutted market where the prices are low. If able to sell their produce at a later date, the producer's returns may have been higher (Arias, 1969: 41).

While there is much money available for the purchase of agricultural machinery, its destination is limited in most cases to the larger wheat producers who have collateral and are not financial risks. The non-institutional credit market does provide money for small agricultural purchases, but it does not have sufficient funds to lend for machinery purchases, even if the desire to do so existed on their part. There must be a shift in emphasis, especially by the state lending agencies, to bring about a more meaningful distribution of credit resources to raise agricultural production and farm income. Within the study area as elsewhere in the in the country, the possible level of agricultural mechanization is greatly influenced by the provision of agricultural credit.

Conclusion

In general reference to the hypotheses of this study it has been shown that there are various physical and agricultural factors which in many ways can affect the level of agricultural mechanization and the yields obtained. Specifically these considerations depict the underlying reasons for problems encountered in using agricultural machinery, or problems in attempting to mechanize.

The general topography limits the ability of the producers to mechanize their agriculture, thereby directly affecting the level of mechanization. The relief also influences the use of machinery and in many instances causes problems for machinery use. Machinery cannot be used in some cases as a direct result of the irregularity or steepness of the topography.

Climatic conditions coupled with altitude and soil types affect both machinery use and the resultant yields. The heavy rainfall received in parts of this area and the clay like soils and high altitudes affect the running operation of the machinery. Rapid changes in soil type or quality on large farms tends to retard the use of machinery due to the necessity of changing fertilizer type and quantity, possibly within the same field.

The agricultural factors influence both machinery use and yields of wheat. The lack of an agrarian structure can often cause many problems encountered in the use of machinery. The total farm size and the area sown in wheat can directly influence the operation of machinery because optimum sizes of both are required for the efficient economic and physical operation of agricultural machinery. The low agricultural wages of this area tend to lessen any economic rationale behind machinery purchase, and they tend to justify machinery use levels prevalent within the area. Low education levels can retard the use of machinery because certain levels of education and technical training are necessary for the efficient operation and upkeep of agricultural machinery. There is a definite lack of both trained machine operators and mechanics in the area. In reference to this, there was also a lack of service and repair centers in reasonable proximity to the producers' farms.

Finally, the quality of extension services and the availability of agricultural credit was shown to be of importance in terms of both machinery use and the resultant yields. Advances in the use of agricultural machinery, as well as increases in wheat production can be retarded by poor and inefficient extension services and a lack of agricultural credit.

CHAPTER III MACHINERY USE INVENTORY AND ANALYSIS

The purpose of this section is to analyze the present use of agricultural machinery, the cost of using both mechanical and non mechanical methods of farming, variations in the levels of agricultural mechanization, the problems of using machinery, the reasons for its non-use, and the variations in yields which were reported within the three study cantons.

The first topic of concern is the actual use of agricultural machinery in terms of soil preparation, seeding and fertilization, and the harvesting of the wheat crop. Related to this is the second purpose which is the comparative analysis of yields, slopes, fertilizer use, and farm size under five levels of mechanization which exist within the study area. The third purpose is to analyze the costs associated with mechanical or non-mechanical farming in terms of farm size, yields, slopes, and the level of mechanization employed. This will be done primarily to demonstrate the relationships which exist between these factors and the costs. Finally, the four hypotheses of this study will be considered.[11]

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11 The order of the hypotheses tested is: 1) reasons for the area's present level of mechanization, 2) the problems of its use, 3) the reasons for its non-use, and 4) the implications of machinery use to wheat production in this area. The structure was felt to be a logical extension of the study's objectives.

Machinery Use

Machinery use varies according to the stage of operation in the three study cantons. It was therefore decided that it would be useful to examine the use of machinery or the non-use under the three operations of wheat production: soil preparation, seeding and fertilization, and harvesting. A short discussion on machine operators, their wage and numbers was also deemed useful.

Soil Preparation

There were ninety-four wheat producers within the three cantons under study who utilized a tractor to prepare their fields for wheat cultivation. Of this total, seventy-four actually owned their own tractor while the remaining twenty rented their tractors. This "custom" tractor work was carried out by those producers who owned the machinery. The average horsepower of the tractors was sixty, but there existed a range from a small tractor of thirty horsepower, to large models with a ninety-five horsepower rating. All tractor owners possessed a plow and disk harrow by which they could prepare the land for seeding.

As an alternative to the use of agricultural machinery, fields were also prepared by a junta or team of oxen. There were forty-five producers who used this means of preparing their land for cultivation. Of these forty-five farmers, only ten actually owned their own cxen. There were no wheat producers within the study area who plowed their land by purely manual methods.

Considering all wheat producers within the study area, the mean cost of preparing the land for wheat seeding was 637.82 sucres ($26.95 U.S.) with a standard deviation of ±510.54 sucres ($20.42 U.S.) for every hectare.[12] Overall preparation costs ranged from fifty sucres ($2.00 U.S.) to a maximum of 2000 sucres ($80.00 U.S.) per hectare. Those producers using a tractor had an average cost of 924.16 sucres ($36.96 U.S.) while producers not using machinery averaged only 112.57 sucres ($4.50 U.S.) for every hectare they prepared for wheat planting.

Seeding and Fertilization

In the seeding and fertilization stage of wheat production there was far less use of machinery that was used to prepare the land. Only thirty-one of the 140 wheat producers of the area used a seeder-fertilizer machine. A further two producers utilized a seeding machine, spreading fertilizer with an independent machine. One producer spread seed by hand but used a tractor-drawn fertilizer spreader.

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12 Only costs incurred in the actual use of the machinery at each stage of the cultivation process were included, i.e. fuel and depreciation. For those producers who used manual methods, the costs were calculated in terms of the wages paid to the farm workers. All costs with the exception of the harvest were reported on the basis of one hectare. Costs for the harvests could only be reported in terms of the cost for every quintal of wheat harvested. Seed and fertilizer cost, etc, were not entered into the costs of using either mechanical or non-mechanical methods.

Therefore, excluding all producers spreading seed manually, there were thirty-three producers in the three cantons who used mechanization in this stage of wheat cultivation. Of these, twenty-nine owned their own machinery, while four rented other producers' units for seeding and fertilizing their fields. The lack of custom work at this stage of the cultivation process partially accounts for the low level of mechanization.

The majority of the producers seeded and fertilized by the "broadcast" method, thereby providing some work for the agricultural workers of the area; a mean of five men were employed to seed and fertilize one hectare of land. The individual farmer or his family often performed these operations themselves, especially on small farms, thereby eliminating the need to hire outside labor.

In terms of costs, it was found that there was a mean expenditure of 123.72 sucres ($5.00 U.S.) ±84.83 sucres by all producers considered together for the seeding and fertilization processes. The costs of these operations varied from zero (0), where the farmer did his own seeding, to a maximum of 400 sucres ($16.00 U.S.). Those producers using machinery had a higher average cost of 172.42 sucres ($7.00 U.S.) compared to those producers who did not use machinery and who had an average cost of 98.64 sucres ($4.00 U.S.)

Harvesting

There were three distinct types of harvesting practices used within the three cantons. The first of these was the utilization by wheat producers of a combine which cuts and threshes the wheat in one operation. For the purposes of this study this use was considered as mechanization because of the mobility of the combine. The second type of harvesting procedure practiced by the area's wheat producers was the manual cutting of the wheat and the use of a threshing machine to separate wheat from straw. The third method practiced was manual cutting of the wheat and the use of an animal to thresh the wheat.

The first method of harvesting wheat with a combine was practiced by eighty-one wheat growers which is a majority of this area's producers. Of this total, twenty-two owned their own combines, while the remaining fifty-nine employed custom combining services provided by those who owned this type of machinery.

The second method, manual cutting and the employment of a threshing machine, was advantageous in areas where the use of mobile machinery was impossible or in some way inadequate. In total there were thirty-six wheat producers in the study area who used a threshing machine in their harvests, but only four of these owned their own machines. Custom threshing has an important function, therefore, within the study area. In reference to the cutting of the wheat, there was an average of eleven agricultural workers employed from the local agricultural labor force per hectare to cut and carry the wheat to the threshing machine. Some producers hired as many as twenty-eight persons to perform this function, while others hired as few as five workers per hectare.

The third type of harvest practiced within the study area is similar to the previous method in terms of a manual cutting operation. Instead of a mechanical threshing machine, these producers employ an animal to thresh the wheat. There were twenty-three producers who practiced this form of harvest and of this total, eighteen owned their own animals. The wheat producers who practiced this type of harvest also employed far less people to perform the cutting operation. The mean number employed by this group of twenty-three wheat producers, other than family members, was five agricultural workers for every hectare of wheat cultivated.

The cost of using agricultural machinery or alternative methods was reported as a set number of sucres per quintal of wheat harvested. The reason for this was that a great number of the wheat producers used custom hiring services and were charged for these services in this manner.[13] This rate varied positively in relation to the distance the machine had to travel and the accessibility of the wheat fields. The mean cost of harvesting by mechanical or non-mechanical methods for all wheat producers within the study area was

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13 Ninety-six of the wheat producers rented either machinery or an animal to perform their harvests for them. Fifty-nine producers hired combines; thirty-two hired threshing machines, and five producers rented the animal they used to thresh wheat.

11.68 sucres for every quintal of wheat harvested, with a standard deviation of ±4.56 sucres. The range of costs per quintal of harvested wheat varied from a minimum of four sucres to a maximum of thirty-nine sucres.

Producers who employed a combine for their harvests paid a mean of eleven sucres per quintal of wheat harvested ($0.50 U.S.) with a standard deviation of ±2.1 sucres, while those who cut wheat manually and used a threshing machine paid a mean of 13.97 sucres per quintal of wheat harvested, with a standard deviation of ±6 sucres. Producers who cut wheat manually and employed an animal to thresh their wheat paid the lowest costs for their harvests because they assessed a flat rate to the cost of the animal used and hired less agricultural workers. Nevertheless, they paid a mean of 10.61 sucres per quintal of wheat harvested with a standard deviation of ±4.19 sucres.

Machine Operators

Sixty-four machine operators were employed within the study area, operating both tractors and combines. The mean wage paid to these trained personnel was 973.13 sucres ($38.92 U.S.) per month, with a standard deviation of ±262.08 sucres. The range of wages paid to machine operators varied from a minimum of 450 sucres ($18.00 U.S.) to a maximum of 1,600 sucres ($64.00 U.S.) per month. Figure 21 shows the distribution of wages paid to the machine operators within the study area. Thirteen of the sixty-four operators received

Monthly Wages Paid to Machine Operators (Sucres)

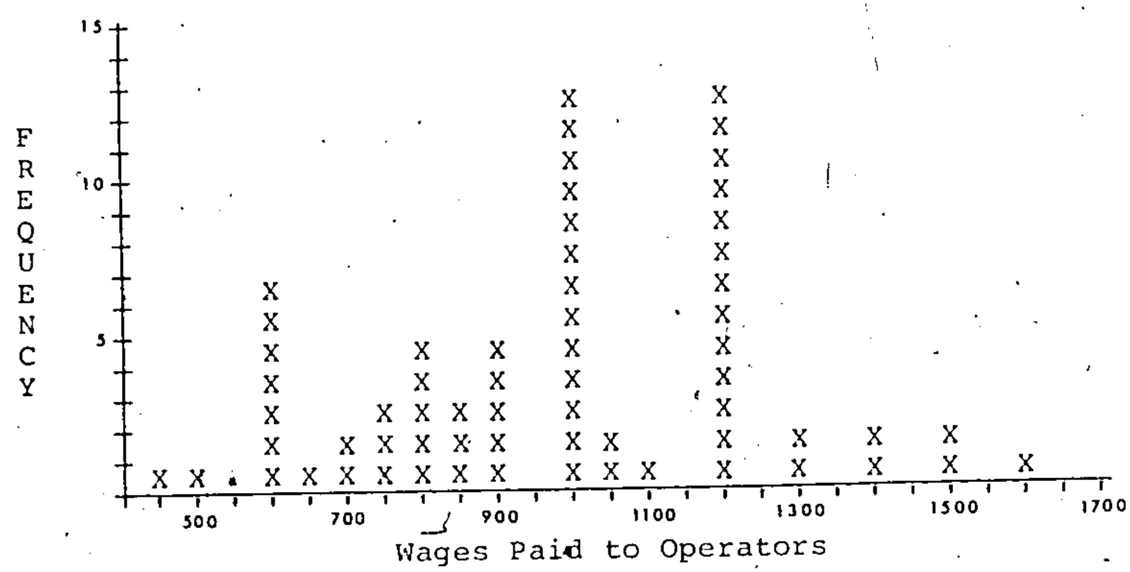

Figure 21

1,000 sucres per month ($40.00 U.S.), while an additional thirteen received 1,200 sucres ($48.00 U.S.) per month. Nearly fifty per cent (28) of these machine operators received less than 900 sucres ($36.00 U.S.) per month for the function they perform in the production of wheat.

Comparative Analysis of Levels of Mechanization

Table 13 illustrates, by the five levels of mechanization in the study area, the variations in other factors of production which are either a result of the level of mechanization or influence it in some manner.

The size of farm, size of wheat field, total area under cultivation, and total per cent cultivated vary considerably by the level of mechanization practiced. In terms of total farm size, those producers who utilize full mechanization have a mean property size of 413.29 hectares. This mean compares with means of 240.90, 99.50, 11.96, and 4.04 hectares for producers using a tractor-combine, tractor-thresher, thresher, and no mechanization, respectively. The size of the farm often dictates the degree of credit availability and extension services available to these wheat producers because these services are often only available to the larger farm owners. As the mean farm size decreases there is also a tendency for the level of agricultural mechanization to decrease as well.

Wheat field size decreases in much the same manner, with the fully mechanized farmer cultivating a mean of 42.7

Table 13 The Comparison of Various Factors By the Level of Mechanization in Practice in Cantons Mejia, Quito, and Ruminhaui

Factor			Level of Mechanization				
			Fullmech[1]	Tracomb[2]	Tractres[3]	Thresher[4]	Nomech[5]
Number	Producers		31	50	14	22	23
Location	Mejia		18(46)[6]	22(46)	4(46)	2(46)	0(46)
	Quito		11(90)	27(90)	9(90)	20(90)	23(90)
	Ruminhaui		2(4)	1(4)	1(4)	0(4)	0(4)
Distance (Km)	Nearest Town		4.194	5.160	3.786	3.318	3.435
	Canton Capital		10.581	15.320	15.929	29.045	32.957
	Quito		26.548	23.940	22.857	30.545	32.957
Size (Ha)	Farm	Mean	413.290	240.900	99.500	11.955	4.043
		S.D.	653.863	363.147	103.923	23.243	3.914
	Field	Mean	42.710	17.000	2.643	3.273	1.130
		S.D.	59.083	30.313	2.530	3.894	0.344
	Total Cultivated	Mean	291.258	189.500	86.000	11.955	4.043
		S.D.	439.389	263.134	104.077	23.243	3.914
	% Cultivated	Mean	87.600	86.400	81.600	100.000	100.000

Table 13 (Continued)

Factor		Level of Mechanization				
		Fullmech	Tracomb	Tractres	Thresher	Nomeoh
Yield (QQ/Ha)	Mean	39.355	30.040	28.214	13.318	9.522
	S.D.	19.672	14.886	17.357	5.093	3.073
Slope (°)	Mean	5.839	6.000	5.429	17.091	20.783
	S.D.	2.709	2.466	2.652	4.286	3.872
Fertilizer (QQ/Ha)	Mean	5.355	3.740	2.071	1.864	1.043
	S.D.	2.470	1.794	1.592	1.490	1.331
Own Tractor	#	29	38	7	---	---
	%	93.5	76.0	50.0	---	---
Horsepower	Mean	65	59	55	---	---
Own Oxen	#	---	---	---	6	4
	%	---	---	---	27.3	17.4
Own Fertilizer - Seeder	#	---	---	---	---	---
	%	74.2	---	---	---	---
# of Men to Fertilize and Seed	Mean	---	---	12	9	5

Table 13 (Continued)

Factor		Level of Mechanization				
		Fullmech	Tracomb	Tractres	Thresher	Nomech
Own Combine	#	17	5	---	---	---
	%	54.8	10.0	---	---	---
Own Thresher	#	---	---	2	2	---
	%	---	---	14.3	9.1	---
Own Animal For Harvest	#	---	---	---	---	18
	%	---	---	---	---	78.3
# of Men to Harvest	Mean	---	---	12	9	5

1 Fullmech = full mechanization or the use of a tractor, fertilizer-seeder and a combine.

2 Tracomb = the use of a tractor, manual seeding and fertilization and a combine.

3 Tractres = the use of a tractor, manual seeding, fertilization and cutting, but the use of a threshing machine.

4 Thresher = the use of an oxen to prepare the land, manual seeding, fertilization and cutting, but the use of a threshing machine.

5 Nomech = oxen to prepare the land, manual seeding, fertilization and cutting and the use of an animal to thresh the wheat.

6 Values in brackets total number of wheat producers in the canton.

hectares of wheat, and the non-mechanized farmer cultivating a mean of 1.13 hectares. This is of course proportional to the mean number of hectares in the total farm, and small wheat field size renders the use of machinery inefficient. Also of interest is the small mean wheat field size of the producers who use a tractor and a thresher, and who, with a mean of 103.92 hectares in their properties, cultivate only 2.6 hectares of wheat; this is less than producers who use only a thresher. The desire to cultivate such a small area of wheat could be responsible for their relatively low level of mechanization or vice versa because of high machinery costs.

Generally, the total percentage of land under cultivation increases as the level of mechanization decreases; this is due to the inverse effect of total farm size and the desire to use land for crops. The smaller the farm size, the more land that is put into crops. Producers using full mechanization, a tractor-combine or a tractor-thresher, utilize an average of 85.2 per cent of their land for crop cultivation, including wheat. The other two levels of mechanization, threshing machine users and those who do not use machinery, both use one hundred per cent of their holdings for crops.

The yields obtained also increased as the level of mechanization increased. It is useful to consider slopes and fertilizer as well within this discussion. Measured slopes decreased as the level of yields and mechanization increased. As higher levels of mechanization and yields were reported, there was also a corresponding increase in the use of chemical fertilizer. Producers who were fully mechanized had a mean yield of 39.36 quintals of fertilizer per hectare, while being located on mean slopes of 5.84 degrees. This can be compared with producers who used no mechanization, and had a mean yield of 9.52 quintals per hectare. They used a mean of 1.04 quintals of fertilizer per hectare and farmed on slopes with a mean of 20.78 degrees. There were intricate relationships, therefore, between yields, fertilizer use, machinery use, and slopes in the three cantons. Equally important were climatic considerations and the quality and type of soil that the producers had to work with. Generally, fully mechanized farmers were located in the Cwb climate areas and in the moist sierran soil group, which are considered best for wheat production.

A higher proportion of those farmers who used full mechanization processes owned their own equipment. This was a result of their relative ease in obtaining agricultural credit, due to their average larger farm size in comparison to the other levels of machinery users. In terms of tractor use, 93.5 per cent of the producers who were fully mechanized owned their own tractors, which compared to a seventy-six per cent ownership rate for the tractor-combine level and fifty per cent for the tractor-thresher level of mechanization. For combines, 54.8 per cent of the fully mechanized farmers owned their own machine, while only ten per cent of the tractor-combine users who are the next lowest level of mechanization, owned their own machines. For threshing machine users, only 23.4 per cent of the thirty-six owned their own equipment, which reflects the low availability of credit within the area, as well as the obsolescence of threshing machine purchase in general.

In summation, it was shown that farm size and wheat field size decreased as the level of mechanization decreased, but that there was a fuller use of total lands as the level of mechanization decreased. This was probably reflective of farm size in general and the wish to utilize the total farm when the size was small. Fully mechanized farms were located on flatter land than were the other mechanization groupings, with the non-mechanized farmer being located on steep slopes; these facts reflected the differences in levels of mechanization, and affected the costs of using mechanical or non-mechanical methods.

Total Cost of Mechanical or Non-Mechanical Methods

The total cost of using agricultural machinery or alternative agricultural methods varied considerably throughout the study area.[14] Considering all wheat producers, there was a range of 2,945 sucres ($100.00 U.S.) in the total costs of producing wheat in this area. The lowest cost was 130 sucres

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14 Total costs of producing wheat are for each hectare of wheat cultivated.

($5.00 U.S.), while the maximum cost recorded was 2,625 sucres ($105.00 U.S.). The mean cost of wheat production in the study area was 1,066.50 sucres ($42.66 U.S.), with a standard deviation of ±666.05.

Total Costs By Mechanization Levels

Table 14 shows the costs of wheat production by the five levels of mechanization selected for the study area. This table shows not only the total cost, but also the costs for each stage of the wheat cultivation process. As previously indicated, the cost of the harvest was in units of sucres per quintal of wheat harvested. To arrive at a cost for this table the mean rates of harvest cost for the five levels of mechanization were multiplied by the average yield, 25.921 quintals for the whole study area. Although this mean yield is not truly reflective of the five levels of mechanization, it does allow for a constant cost factor for the harvest to be presented. Of particular interest is the fact that those producers who use a tractor and a combine. The mean yield of 28.21 quintals per hectare obtained by these producers at a higher cost is far less than the 39.36 quintals obtained by those producers who were fully mechanized. Of course other factors such as slope and fertilization have to be considered for a full analysis of this situation. Generally, total costs decreased as the level of mechanization decreased.

Table 14 Average Costs of Wheat Production in Cantons Mejia, Ruminhaui and Quito

Variable	Fullmech[1]	Tracomb[2]	Tractres[3]	Thresher[4]	Nomech[5]
Mean Yields	39.36	30.04	28.21	13.32	9.52
Preparation Cost	997.74	887.60	997.14	111.82	113.26
Seeder-Fertilizer Cost	172.42	147.42	109.29	95.46	42.39
Harvest Cost[6]	282.62	286.69	372.15	352:29	275.00
Total Cost	1,452.78	1,321.71	1,478.58	559.56	430.65

1 Fullmech = use of full mechanization.

2 Tracomb = use of only a tractor and a combine.

3 Tractres = use of only a tractor and a threshing machine.

4 Thresher = use of a threshing machine only.

5 Nomech = use of no-machinery at all.

6 Calculated on the basis of 25.91 quintals per hectare yield, the mean for the study area in its entirety.

Total Costs By Farm Size

Table 15 shows the total costs of using agricultural machinery, or the alternative methods, by the various size categories of farms. It is shown that as the total costs increase from three hundred sucres per hectare ($12.00 U.S.) to 2,700 sucres ($108.00 U.S.), the farm size also increases. It has been found that there is a positive correlation of 0.667 between the total costs of using farm machinery and the sizes of the farms in the study area (0.01 significance level).

On farms of less than five hectares, nineteen of the thirty-one producers in this size category utilized less than three hundred sucres in total costs for machinery use or its alternative, while a further five had total costs between three hundred and six hundred sucres. In general, farms of less than twenty hectares have total average costs between nine hundred and eighteen hundred sucres, reflecting their lower level of mechanization. Seventy-six producers have total costs which are less than twelve hundred sucres, while sixty-four utilized a greater amount of money for the mechanization of their wheat production. Figure 22 shows the general trend of increasing farm size against increasing costs. Costs rise moderately until a level where the use of agricultural machinery is more widespread. At this point there is a substantial difference in the total expenditures by farm size, which can be explained solely by the variations

Table 15 Total Cost of Machinery Use By Farm Size in Cantons Mejia, Quito and Ruminhaui.

Farm Size (Has)	Total Cost (Sucres)									
	≤300	300-599	600-899	900-1199	1200-1499	1500-1799	1800-2099	2100-2399	2400-2699	Total
<0- 4.9	19	5	2	2	2	0	1	0	0	31
5- 9.9	8	3	4	2	0	0	0	0	0	17
10- 19.9	3	2	1	0	0	0	0	0	0	6
20- 49.9	0	0	0	3	4	1	1	0	0	9
50- 99.9	0	1	2	0	6	3	0	1	0	13
100-199.9	0	0	3	8	5	5	5	3	2	31
200-499.9	0	0	0	4	5	6	0	0	2	17
500-999.9	0	0	3	1	3	1	2	0	1	11
>1000	0	0	0	0	0	3	2	0	0	5
Total	30	11	15	20	25	19	11	4	5	140

Generalized Trend of Total Cost of Using Machinery By Farm Size

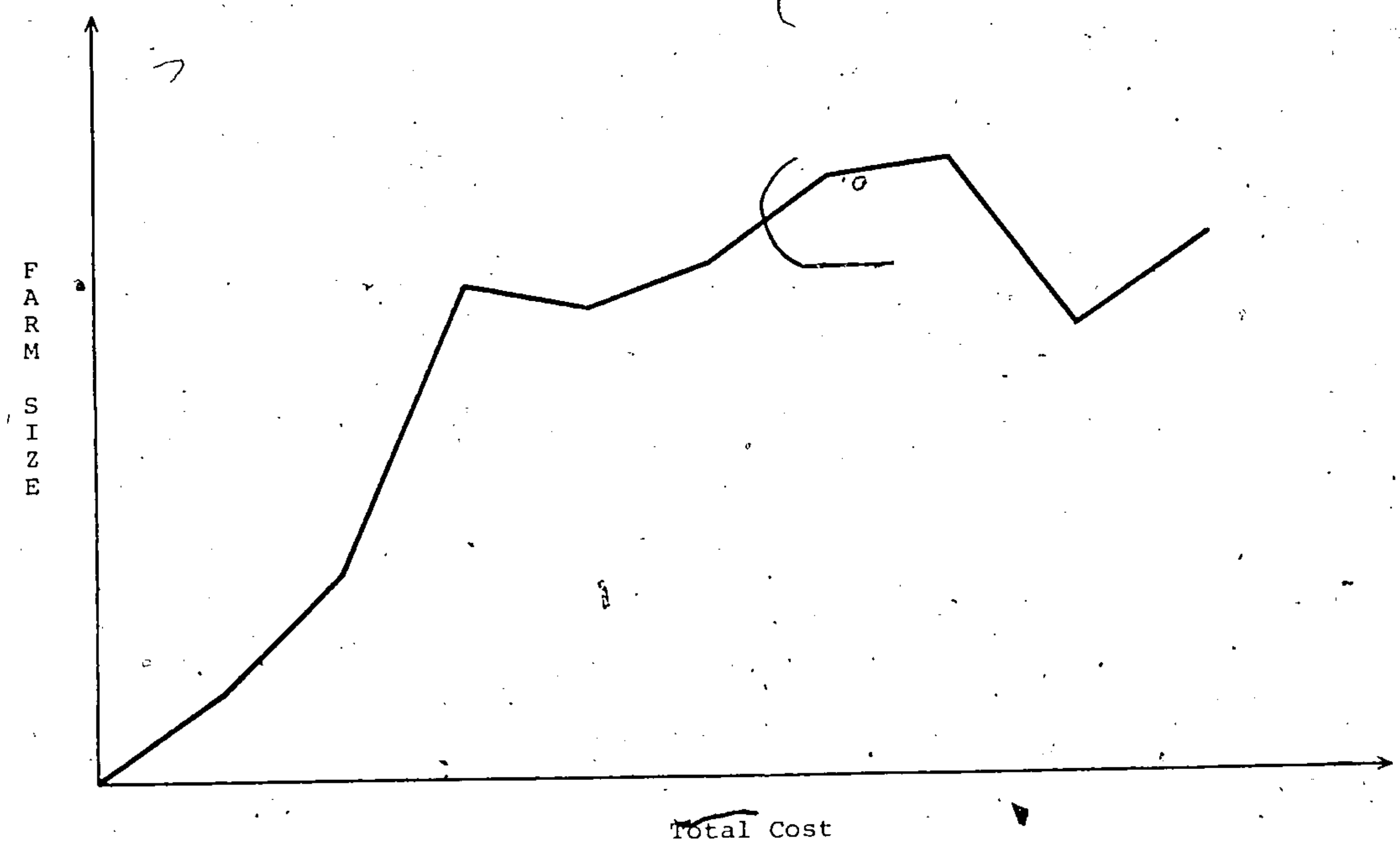

Figure 22

in the level of mechanization and associated practices throughout the study area.

Total Costs By Field Slope

Table 16 shows the total costs of using either agricultural machinery, or alternative methods, as they vary according to the slope of the fields under wheat cultivation. On slopes which are less than twelve degrees, the costs of producing wheat are much higher than the costs above this level. The reason for this is that below slopes of twelve degrees wheat producers are able to mechanize their production, while above this level machinery is not used. There is a negative correlation of -0.613 between the total costs of using machinery and the slope of the wheat field (0.01 significance level).

The average cost of those producers below twelve degrees of slope is between twelve hundred and fifteen hudred sucres. Any deviations from these figures can be explained by differences caused by variations in the actual levels of mechanization practiced by these producers. None of the ninety-seven producers located on slopes of less than twelve degrees use less than three hundred sucres in total costs, and only two of these use less than six hundred sucres.

Figure 23 shows the general trend of this situation in the study area. There are low machinery use costs in areas of high angles, but as the slope decreases, particularly

Table 16 Total Costs of Machinery Use By Farm Field Slope In Cantons Mejia, Quito and Ruminhaui.

Farm Field Slope(°)	Total Cost (Sucres)									
	<300	300-599	600-899	900-1199	1200-1499	1500-1799	1800-2099	2100-2399	2400-2699	Total
0-2	0	0	2	1	0	2	1	1	1	8
3-5	0	2	6	6	10	5	3	0	2	34
6-8	0	0	4	11	11	6	5	1	0	38
9-11	0	0	2	1	5	3	2	2	2	17
12-14	2	0	0	0	0	0	0	0	0	2
15-17	7	2	2	1	0	0	0	0	0	12
18-20	5	6	0	0	0	0	0	0	0	11
21-23	8	2	0	0	0	0	0	0	0	10
24-26	7	0	0	0	0	0	0	0	0	7
27-20	1	0	0	0	0	0	0	0	0	1
Total	30	12	16	20	26	16	11	4	5	140

Generalized Trend of Mean Total Cost of Using Machinery By Field Slope

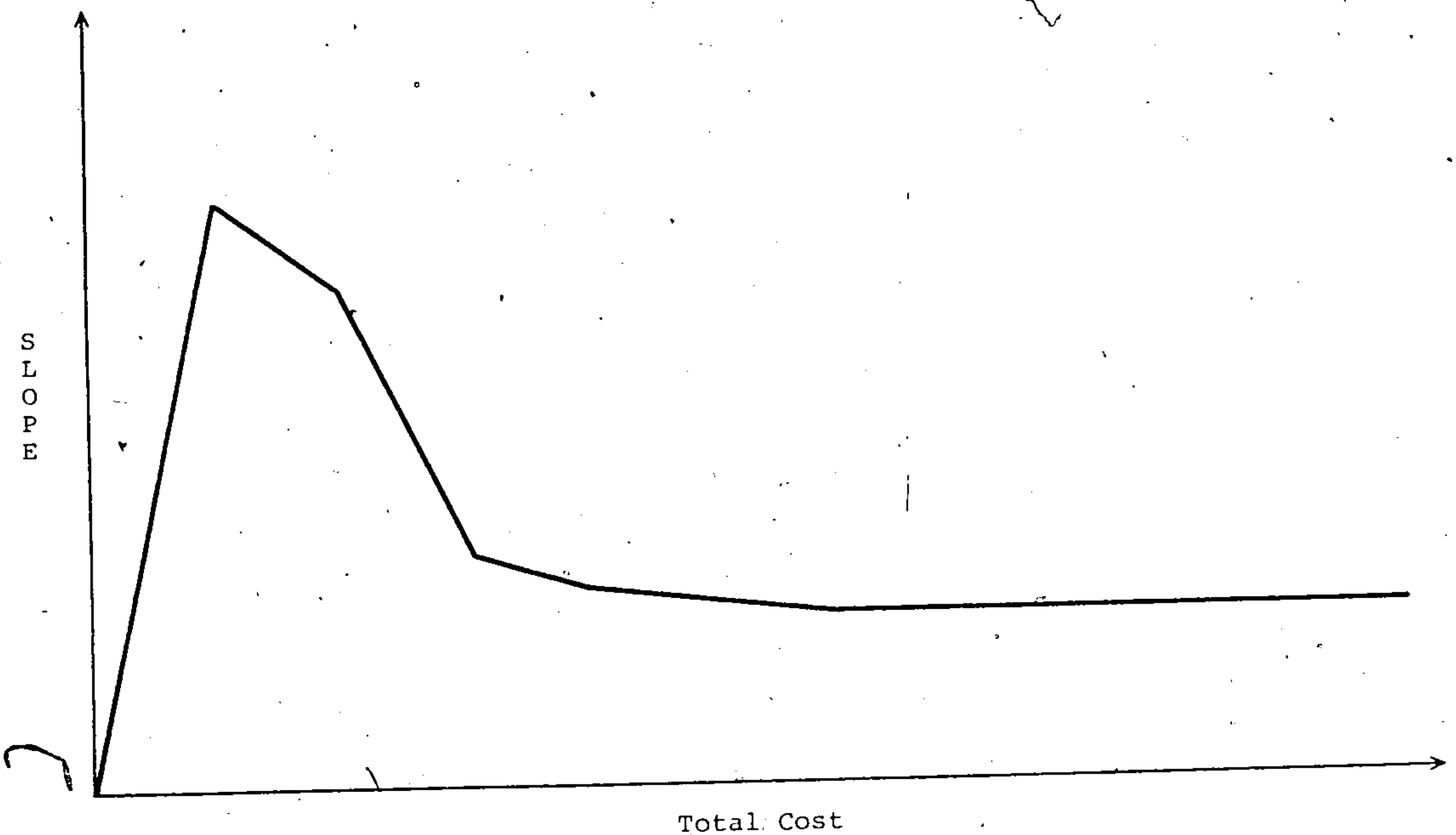

Figure 23

below eight degrees, these total costs increase rapidly. This of course reflects the variations in degree of mechanization from the use of only a threshing machine to the use of full mechanization in the wheat production.

Total Costs By Reported Yields

Table 17 shows the total costs of using machinery, or alternative methods, by yields obtained within the study area. There is a positive correlation of 0.769 between the total costs of using machinery and the yields obtained (0.01 significance level).

This table shows that the lower the expenditure on machinery use, the lower will be the yields. It must be pointed out that this is also partially indicative of farm size and slope, as well as other factors which will be tested in the fourth hypothesis. Forty-seven producers, whose total costs were less than nine hundred sucres, had yields of fifteen quintals or less per hectare of wheat cultivated. Those producers whose total costs were greater than nine hundred sucres had yields which varied from ten quintals to ninety quintals per hectare, but their average yield was thirty quintals per hectare. The wide range in yields obtained for this group was in response to variations in the level of mechanization and fertilizer application, more so than from any other group of factors.

Figure 24 shows the general trend of increasing costs against the resultant yields obtained. The relationship

Table 17 Total Costs of Machinery Use By the Resultant Yields in Cantons Mejia, Quito and Ruminhaui.

Yields (QQ/Ha)	Total Cost (Sucres) <300	300-599	600-899	900-1199	1200-1499	1500-1799	1800-2099	2100-2399	2400-2699	Total
< 10	14	2	1	1	0	0	0	0	0	18
10-15	16	9	5	2	0	0	0	0	0	32
16-20	0	2	6	6	7	3	1	0	1	26
21-25	0	0	1	0	1	0	0	0	1	3
26-30	0	0	1	3	8	4	2	1	1	20
31-35	0	0	0	0	2	1	0	0	0	3
36-40	0	0	1	4	3	2	1	0	1	12
41-45	0	0	0	1	1	2	2	0	1	7
46-50	0	0	0	1	2	2	4	2	1	12
> 50	0	0	0	2	1	2	1	1	0	7
Total	30	13	15	20	25	16	11	4	6	140

Generalized Trend of Mean Total Cost of Using Machinery By Yields Obtained

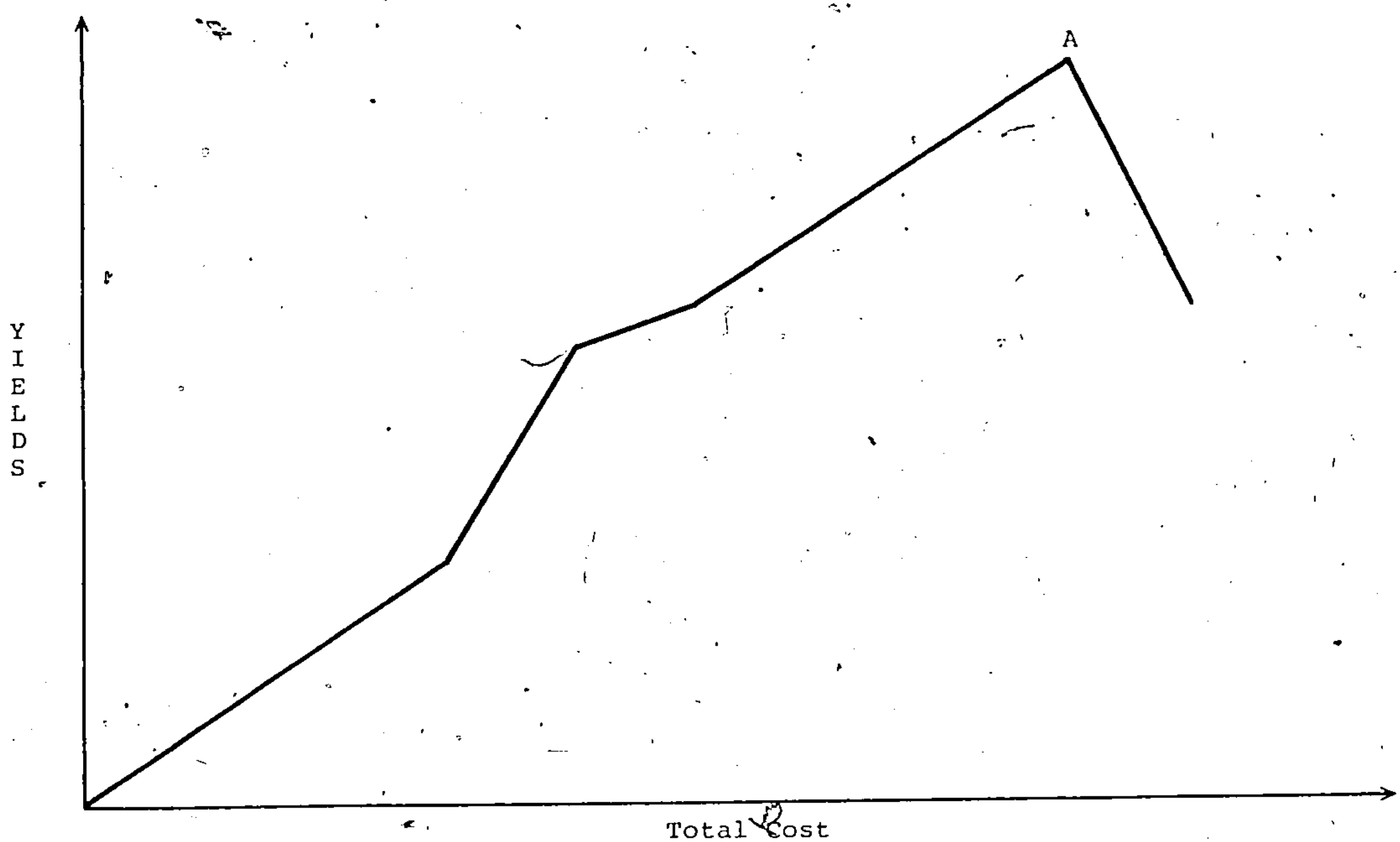

Figure 24

which exists is such that as costs rise steadily, the yields increase in a corresponding manner. At point A any further capital input will not cause any further increases in yields. The graph actually shows that for producers who use greater amounts of capital than depicted at point A, there will actually be an average decrease in yields. Beyond this point capital will therefore be unproductive and inefficient.

Conclusion

The total cost of using machinery, or the alternative method, has been shown to vary according to the level of agricultural mechanization, slope of the wheat field, and farm size. These variables form a network of interrelationships; the cost of using machinery varies with the level of mechanization, which varies somewhat according to farm size, which is often dictated by wheat field slope. There is a negative correlation of 0.5402 between farm size and the wheat field slope. Therefore, as the slope increases, farm size decreases; the level of mechanization which has a positive correlation of 0.36305 with farm size, also decreases. As will be illustrated later, the resultant yields are a direct result of the interrelationships within these factors.

Hypothesis 1

The level of agricultural mechanization varies considerably within the three cantons. Stepwise multiple regression analysis was employed to explain the variation caused by selected independent variables on the area's level of mechanization.[15] The first hypothesis, restated, is:

HO 1 Variations in the level of agricultural mechanization throughout the study area are a positive function of:

a) farm size,
b) wheat field size,
c) hectares under cultivation,
d) closeness to the nearest town,
e) closeness to the canton capital,
f) closeness to Quito,
g) low angle of slope of the wheat field.

Table 18 shows the results of the stepwise multiple regression on the dependent variable, level of mechanization, by the seven indicated independent variables.[16] The slope of the wheat fields has a simple correlation of -0.77135 with the level of mechanization, and explains fifty-nine per cent of the variation in levels of mechanization. The field slope is therefore the largest single explanatory variable of the mechanization which has taken place in this area. The hectares under wheat cultivation have a moderately high positive correlation of 0.35762 with the level of mechanization, and explain a further 3.8 per cent in the variation in agricultural levels of mechanization. The total number of hectares under cultivation which influences the total farm

15 All computer programs used in this study's analysis were taken from Statistical Package For the Social Sciences by Nie, N. et al. McGraw-Hill Book Company, Toronto.

16 A summary of the step-by-step regression of levels of mechanization can be found in Appendix B.

Table 18 Stepwise Regression of the Level of Mechanization By Farm Size, Hectares in Wheat Hectares Under Cultivation, Distance to Nearest Town, Canton Capital, and Quito, and Wheat Field Slope in Cantons Mejia, Quito and Ruminhaui.

Dependent Variable = Levlmech

Step	Independent Variable	Multiple R	R Square	RSQ Change	Simple r	Regression Coefficient
1	Slope	0.77135	0.59499[1]	0.59499[1]	-0.77135[1]	-0.12671
2	Hectares in Wheat	0.79577	0.63325[1]	0.03826[1]	0.35762[1]	0.00806
3	Hectares Under Cultivation	0.80162	0.64259[1]	0.00934[1]	0.37331[1]	0.00152
4	Distance to Canton Capital	0.80569	0.64914[1]	0.00654[1]	0.44855[1]	-0.02176
5	Distance to Quito	0.81347	0.66173[1]	0.01259[1]	-0.13811[1]	0.01844
6	Distance to Nearest Town	0.81665	0.66691[1]	0.00519[2]	0.16058[1]	0.03576
7	Hectares in Total Property	0.81919	0.67101[1]	0.00416[3]	0.36305[1]	-0.00079
	Constant				3.11377	

1. Significant at .01 level.
2. Significant at .05 level.
3. Not significant.

use and efficiency of machine ownership, had a simple correlation with machinery levels of 0.37331. This explained nearly a further one per cent of the variation in the area's mechanization. The distances of the individual farms from the nearest town, canton capital, and Quito together explained a further 2.4 per cent of the variation. These were significant due to the servicing and repair services they provide to machinery users. The distance to Quito, where advanced servicing and repair facilities exist, explained 1.3 per cent of this 2.4 per cent total in variation.

It is interesting to note that the actual total farm size was not significant in explaining variations in the use of agricultural machinery. The probable reason for this is that the areas in wheat and the total area cultivated are more instrumental in any decision to use machinery than is total farm size. Custom hiring services are also fairly well developed in the study area and a number of the smaller farms are located near town in relatively flat areas, particularly in Canton Mejia.

In summation, it has been found that slope, hectares in wheat, hectares under cultivation, and distances to service centers explained nearly sixty-seven per cent of the variations of level of mechanization practiced within the study area. In terms of the first hypothesis, all but the total farm size did in fact explain the variations found in levels of machinery use. Slope alone was a great explanatory variable, explaining 59.5 per cent of the variation in machinery use.

In terms of the unexplained variation, it is probable that the physical limitations imposed by soil and climate types were significant. Agricultural factors should be considered also, such as low agricultural wages and problems in the use of machinery, to be discussed in the second hypothesis.

Hypothesis 2

For those ninety-five producers within the study area who did use some mobile machinery, various problems were encountered in its use. This situation will be discussed, and the second hypothesis tested using responses received from an open question on this topic. The second hypothesis, restated, is:

> HO 2 The problems encountered by those producers who did use machinery in their agriculture are:
>
> a) obtaining spare parts,
> b) obtaining them at a reasonable cost,
> c) obtaining repairs,
> d) steepness or irregularity of their land.

The four problems shown in Figure 25 which were encountered by the area's producers in using machinery, were all inclusive, as no other problems were reported. The problems can easily be divided into two groups, physical and agricultural infrastructural. The one physical problem en-

Problems in Using Machinery in Cantons
Mejia, Quito, and Ruminhaui

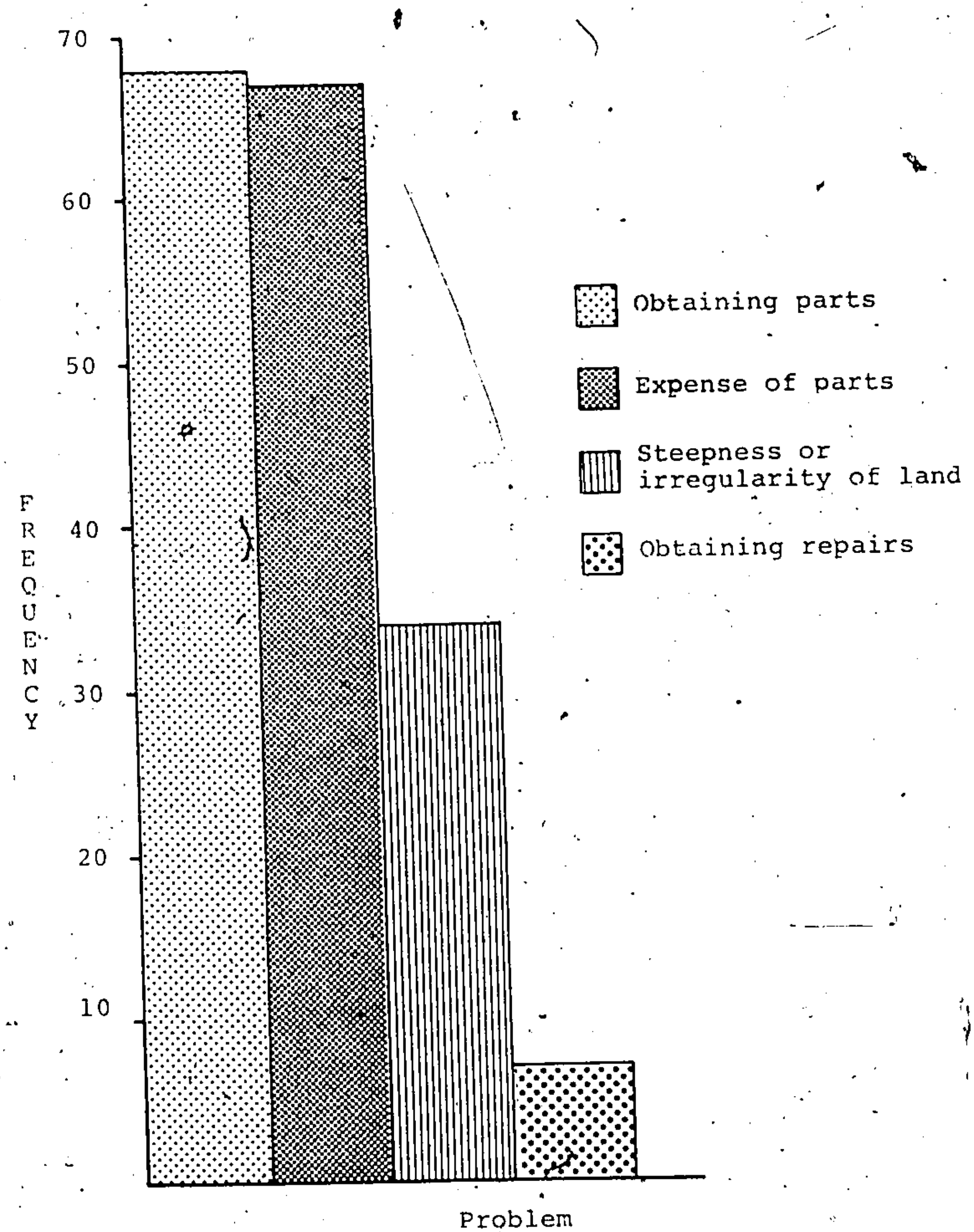

Figure 25

countered by the wheat producers was the use of machinery on parts of their farms which were either too steep or too irregular. The problem was reported by thirty-four of the ninety-five producers who used machinery. Without the special expensive adaptation of agricultural machinery, this problem does not lend itself to an easy solution. Much of this problem centered on the use of machinery on steep slopes in particular, which when somewhat wet, rendered machinery inoperable.

The remaining three problems encountered by producers using machinery were all due to a poor infrastructure for the servicing, care, and repair of agricultural machinery. These three problems were obtaining spare parts, the high expense of these parts when available, and difficulties in obtaining machinery repairs. Sixty-eight of the ninety-five producers who used machinery felt that parts were not available when the need for them arose. Sixty-seven of this total number of machinery users also felt that parts, if available, were grossly overpriced. Together, these two factors directly affect any decision by wheat producers to further mechanize their farming, or to begin to mechanize it.

The third infrastructural problem, difficulties in obtaining repairs, was reported by seven of the ninety-five machinery users. This problem is caused by a lag in the technical training of persons to repair agricultural machinery as well as a relatively poor market for such enterprises. In general, there is a lack of technical schools in Ecuador for such trades as mechanics. The second hypothesis, which states the basic problems of machinery use which exist, is therefore true within the context of the study area.

Hypothesis 3

A total of 109 wheat producers either did not use machinery at all, or used it only in certain stages of their wheat cultivation. In response to an open question on this situation, the third hypothesis was formulated. Restated, it is:

> HO 3 The reasons producers did not use machinery or did not use it in all stages of their wheat production are:
>
> a) machinery was too expensive and they lacked the necessary capital,
> b) hand labor was cheaper,
> c) the land was either too steep or too irregular to use machinery.

Figure 26 shows the number of producers who did not use machinery in all production stages, or not at all, by the reasons for this non-use. The fact that manual labor was both abundant and cheap within the study area was the main reason for the non-use of machinery. Ninety-four of the 109 producers in this category felt that this was the decisive reason why they did not use agricultural machinery for the total process, or did not use it at all. Of particular interest was the seeding and fertilizing operation, where few used machinery. Tied very close to this previous reason is

Reasons for the Non Use of Agricultural Machinery
Either in Whole or in Part in Cantons
Mejia, Quito, and Ruminhaui

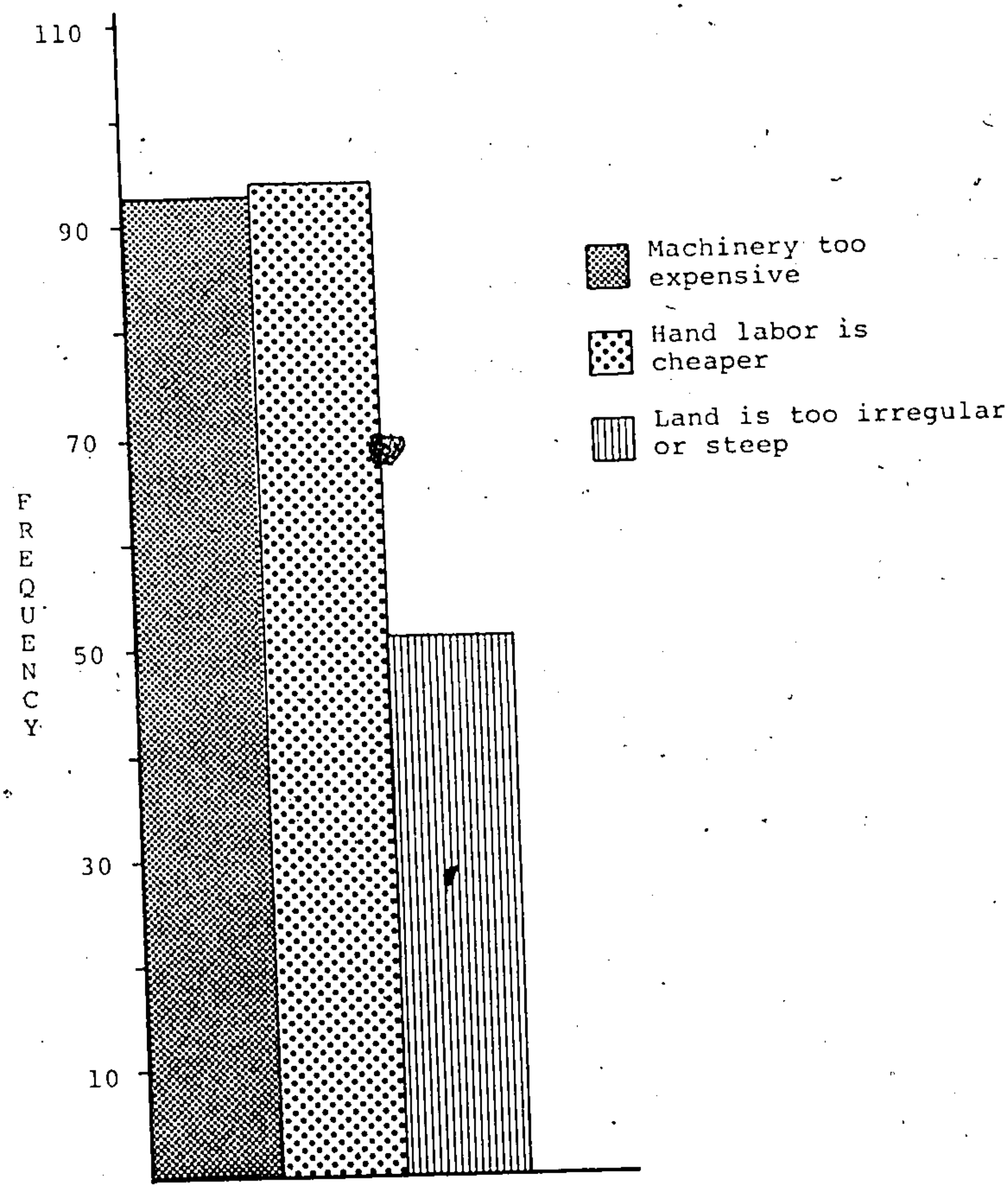

Figure 26

the second reason for the non-use of machinery, its expense and the lack of capital to purchase it. This was particularly true of producers who use no machinery at all. The fact that hand labor was both cheap and abundant no doubt greatly influenced this second reason. Finally, fifty-one wheat producers felt that their lands were either too steep or too irregular for the successful and efficient application of agricultural machinery. The third hypothesis is therefore valid for the area under consideration.

Hypothesis 4

It has been elucidated up to this point that there exists a complexity of interrelationships or influences between the reported yields throughout the study area and various other factors. In order to judge the relative importance of these factors in explaining the variations in reported yields, stepwise multiple regression analysis was employed. The fourth hypothesis, restated, is:

> HO 4 Variations in yields throughout the study area are a positive function of:
>
> a) the property size,
> b) low angle of wheat field slopes,
> c) amount of fertilizer used,
> d) the level of agricultural mechanization.

Table 19 shows the summary of results obtained by the stepwise multiple regression analysis[17] on the dependent

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17 A summary of the step-by-step regrestion of yields can be found in Appendix C.

Table 19 Stepwise Regression of Yield By Farm Size, Fertilizer Used, Field Slope, and the Level of Agricultural Mechanization in Cantons Mejia, Quito and Ruminhaui.

Dependent Variable = Yield

Step	Independent Variable	Multiple R.	R Square	RSQ Change	Simple r	Regression Coefficient
1	Level of Mechanization	0.60069	0.36083[1]	0.36083[1]	0.60069[1]	5.13812
2	Fertilizer	0.63135	0.39861[1]	0.03778[1]	0.52731[1]	1.88400
3	Farm Size	0.64229	0.41253[1]	0.01393[2]	0.32361[1]	0.00552
4	Slope	0.64235	0.41261[1]	0.00008[3]	-0.47530[1]	0.03858
	Constant					6.57751

1. Significant at .01 level.
2. Significant at .05 level.
3. Not significant.

variable, yield, by the independent variables indicated. This analysis shows that the level of agricultural mechanization explains thirty-six per cent of the variations in reported yields. The amount of fertilizer that this area's producers applied to their wheat fields explains a further 3.8 per cent of the yield variations, while farm size accounted for 1.4 per cent of the variation.

It is interesting to note that wheat field slope had little effect upon the resultant yields; it explained only 0.008 per cent of the variation. The R square change from the addition of slope to the regression equation was not found to be significant. The simple correlation between yields and slope, however, was found to be a negative 0.4753.

The level of agricultural mechanization, fertilizer use, and farm size together explained forty-one per cent of the variations in reported wheat yields within the study area. Fifty-nine per cent of the variation in yields is unexplained and is most likely accounted for by other human and physical factors, as well as other agricultural factors such as the type of seed used. The physical limitations imposed by soil and climatic types was probably a consideration in the reported resultant yields within the area. In terms of the final hypothesis, the level of mechanization, farm size, and fertilizer use are proven to account for differences in wheat yields, while slope has little influence. Through the use of machinery and fertilizer, both of which had high correlations with yields, the return in yields could be substantially improved.

CHAPTER IV CONCLUSIONS AND IMPLICATIONS

Conclusions from the Study

Physical and Agricultural Influences

The physical environments of Cantons Mejia, Quito, and Ruminahui influence the use of agricultural machinery in general, but in particular the environment has been shown to affect the level of mechanization significantly. Overall national wheat production has decreased in the last decade, but in recent years, with the more widespread use of fertilizer and agricultural machinery, some rapid increases have been realized. The use of fertilizer varied from zero to fourteen quintals, and this in turn influenced the reported yields (5-90 quintals per hectare). There is still the necessity for more areas to be sown in wheat, but the physical environment greatly influences the amount of land which can be farmed in this area.

The relief of the three cantons directly affects the use of agricultural machinery in a number of ways. Slopes which encircle the Quito Basin are often much greater than twelve degrees in angle, which is the angle of slope above which machinery use is not possible. The slope of the study area's wheat fields varied from one degree to twenty-nine degrees in angle. Ninety-six producers were found to be located on slopes below twelve degrees, the maximum angle of slope on which machinery could be used. The rough and irregular terrain predominating in this area has meant relatively high production costs in using agricultural machinery, caused by higher fuel and repair costs. Altitudes of the wheat producing farms have not only increased fuel consumption of machinery, but have also often caused severe losses of power on the higher slopes.

Climate influenced the use of machinery as well as the level of mechanization. It was shown that because of the short seeding and harvesting seasons the use of agricultural machinery could be of great assistance in increasing wheat yields. Agricultural machinery can perform seeding and harvesting operations much more rapidly than can the more traditional methods; because of this, many of the problems of an ill-timed rainy season are alleviated. Within this area climate can also hinder the use of agricultural machinery. In the higher altitudes of the wheat producing area heavy rainfalls often impede the use of machinery, or cause losses in time, possibly rendering its use inefficient.

The heavy clay-like soils of the higher altitudinal wheat producing areas, in conjunction with these heavier rainfalls, often render machinery inoperable. Rapid switches in soil types are also found in many areas, making the use of different fertilizer formulas necessary. In this case, the use of machinery is somewhat less efficient than if there were large fields of nearly the same soil type. In parts of the study area where the dry sierran soils predominate, there was evidence of severe erosional problems, which also render machinery use less efficient.

All of these physical influences considered together greatly affect the efficient use of agricultural machinery. Losses of power on wet and steep slopes may cause producers to abandon the use of machinery on their land, or cause them not to purchase it at all. The solution is more powerful, specially adapted machinery, but this remedy is often an expensive one which will not be easily accepted by the wheat producers.

Agricultural influences of farm size, education considerations, distances to service centers, and extension-credit services affect the level of agricultural mechanization directly or indirectly in this area. The size of the farm influences mechanization directly insofar as a certain minimal size of farm is necessary for the efficient ownership of agricultural machinery. Farm sizes ranging from one hectare to 2,700 hectares, areas in wheat of one to 320 hectares, and areas under cultivation (8-100%) had considerable effects upon the level of mechanization within the study area. This was due to the effect these variables have on the ability of producers to mechanize their farms in terms of size and capital requirements.

The wages earned by the local supply of labor in this area were sufficiently low enough to affect the degree of mechanization. Many producers felt that greater profits could be realized by using complete or partial manual labor for their wheat cultivation. Of particular note here was the seeding and fertilizing operation which could be done far less expensively using manual labor than machinery.

The level of education prevalent among this area's wheat producers is generally the same as for the national level of rural population. Education levels affect machinery use through the proper running and application of it. If improperly used, machinery may prove less efficient than the more traditional methods. It must be used in conjunction with better seed and fertilizer to display to neighboring producers the advantages of using machinery. Much of the information concerning machinery use, as well as other input factors, is in the form of written literature, and therefore producers must be able to read. Small producers who have little education have greater difficulties in accepting new ideas or innovations, whether they be mechanical or biological.

The availability of trained personnel to operate and repair machinery within the study area was found to be poor. To bring about the successful application of agricultural machinery to this area, the personnel must be provided, through special training programs. Currently, the training of this personnel is lacking in Ecuador. The Government has been generally reluctant to enter into what they consider to be a private sectoral problem.

Service centers offering a variety of agricultural machinery services were of three types, the nearest town, canton capital, and Quito, which is the area's largest center. The nearest towns (0-20 kilometers) offered fuel services and a low degree of preventive maintenance. The canton capitals (2-56 kilometers) provided more advanced mechanical services for agricultural machinery. Quito, the area's largest center (4-56 kilometers) provided the more specialized mechanical services, i.e. transmission repair, as well as serving as a central depot for machinery spare parts.

Agricultural extension services within this area reach only the larger wheat producers. This has partially resulted from a lack of extension workers and transportation for them to use. Also critical were the cultural bottlenecks of extending these services to all groups of people and sizes of farms within the area. Little information on mechanical and biological inputs was reaching the majority of wheat producers in this area. While modes of presenting information to producers were improving, they were found to be deficient in many ways. Again, often only the large producers were encouraged to attend field days where new research experiments were displayed.

Agricultural credit to purchase machinery and other farm inputs was often mis-directed and insufficient. Most funds available for agricultural investment were directed only to the large landholders who were low credit risks and had ample collateral. The private sector provided little agricultural credit and most funds were of government origin. Small to medium size producers were often excluded from the agricultural credit market. Since these producers produce the bulk of the wheat crop in this area, they should be encouraged to modernize through the credit and extension facilities.

The agricultural factors within the study area have been shown to influence both wheat production and the level of agricultural mechanization to a great extent. While not having direct effects upon mechanization as did the physical factors, the agricultural factors are still important in the effects they have on farm modernization in general.

Analysis

The inventory of agricultural mechanization and of related data has portrayed a clearer picture of the degree of agricultural mechanization within the study area. In reference to actual machinery use, ninety-four producers used a tractor for seedbed preparation, with a cost varying from fifty to two thousand sucres ($2.00 - $40.00 U.S.). In the seeding and fertilizing operation there was far less use of agricultural machinery, with only thirty-three of the area's 140 producers using machinery. The remaining producers employed a mean number of five men to seed and fertilize their fields. The mean cost for machinery users was 172 sucres ($6.00 U.S.), while for those producers who did not use machinery, it was ninety-nine sucres ($4.00 U.S.). The harvest was performed in three distinctly different ways within the study area: by the use of a combine, threshing machine, and by the use of an animal to thresh the wheat. Eighty-one producers utilized a combine at the cost of eleven sucres per quintal of harveted wheat; thirty-six producers used a threshing machine costing fourteen sucres per quintal of wheat, and twenty-three producers used an animal to thresh their wheat, which cost eleven sucres for every quintal of wheat obtained.

The mean total cost of using machinery, or its alternative method, was 1,067 sucres ($43.00 U.S.). For producers who were fully mechanized, the mean costs were 1,453 sucres ($58.00 U.S.); for users of a tractor and combine, costs were 1,322 sucres ($53.00 U.S.); for users of a tractor and thresher, the costs were 1,479 sucres ($59.00 U.S.); for users of only a thresher, the costs were 560 sucres ($20.00 U.S.); and for users of no machinery costs were 431 sucres ($17.00 U.S.). Of particular interest were the users of the tractor and a threshing machine who had total costs greater than the fully mechanized farmer, which indicates the inefficiency of this method.

Five different levels of mechanization were found to exist within the study area, and these were selected to show the fluctuations in other factors as the level of mechanization changed. Fifty per cent of all fully mechanized producers and users of a tractor-combine were found to be in

Canton Mejia. This canton was relatively the most mechanized of the three study cantons. Canton Quito contained all twenty-three producers who did not use machinery. While containing only four wheat producers, Canton Ruminahui was highly mechanized as well, in comparison to Canton Quito.

The total area in wheat, area under cultivation, and percentage cultivated were all a direct reflection of total farm size, but all four of these factors varied considerably by the level of mechanization practiced. Fully mechanized farms had a mean property size of 413 hectares, which decreased to four hectares under the category of non-machinery users. Wheat field size decreased in a similar manner to total farm size with fully mechanized farms cultivating a mean of forty-three hectares of wheat and the non-machinery user cultivating a mean of one hectare. Of interest were the users of a tractor and a threshing machine, who while having greater mean property size, actually cultivated less wheat than the next lowest level of mechanization. Producers using mobile machinery cultivated an average of eighty-five per cent of their holdings, while the non-machinery users utilized one hundred per cent of their holdings.

Yields increased as the level of agricultural mechanization increased, reflecting changes in fertilizer use and slope of wheat field as well. Fully mechanized producers who used five quintals of fertilizer per hectare, and who were located on a mean slope of eight degrees, had mean yields of thirty-nine quintals of wheat per hectare. This compares with non-mechanized producers who used a mean of 1.04 quintals of fertilizer, who were located on mean slopes of twenty-one degrees and who had resultant yields of nine quintals per hectare on the average.

In terms of the total costs of using machinery or the alternative methods of production, the analysis showed that as size of farms increased, the total production costs per hectare also increased. This was basically in response to a greater degree of mechanization being utilized as the farm size increased. Slope of wheat field was shown to be significant in determining the total costs of using machinery. Total costs of production were by far greater on farms whose wheat fields were less than twelve degrees than they were on farms having a greater than twelve degree angle of slope. This reflected the ability of those producers below twelve degrees to mechanize their wheat production. To consider also is that some producers did not use fertilizer on steep slopes (i.e. greater than 12°) and the cost of spreading this agricultural input was then removed from their total costs. Total costs below twelve degrees were between 1,200 and 5,000 sucres on the average, based on the ninety-seven producers in this category; the average for the forty-three producers located on slopes greater than twelve degrees was three hundred sucres.

The analysis also showed that the fewer expenditures made by the producers, the less the reported yields would be. If total costs per hectare were greater than nine hundred sucres ($36.00 U.S.) an average yield of thirty quintals per hectare could be expected, in comparison to fifteen quintals for any total costs below this level.

In explaining variations in the level of mechanization reported throughout the study area, the slopes of the wheat fields were found to be of great significance. This variable explained fifty-nine per cent of the variation. Hectares in wheat and hectares under cultivation were also found to be significant in explaining variations because of their effect upon total farm usage of agricultural machinery. The distances to the service centers for agricultural machinery servicing and repairs also contributed significantly to explaining variations in levels of mechanization in the area. Because of the well developed custom hiring services, total farm size was not proven to be a significant factor in explaining levels of agricultural mechanization.

The problems that producers did have when they used agricultural machinery were in obtaining parts, obtaining these at a reasonable cost, obtaining machinery repairs, and in using agricultural machinery on steep or irregular land. For those producers who did not use machinery at all, or who used it in only certain stages of their wheat cultivation, the reasons were that hand labor was both abundant and cheap, there was a general lack of capital to purchase machinery which was felt to be expensive in any case, and finally, the producers' landholdings were either too steep or too irregular for the successful application of agricultural machinery.

Through the use of regression analysis it was found that variations in the yields within the study area could be explained primarily by the level of agricultural mechanization practiced by the wheat producers. This variable accounted for thirty-nine per cent of the variation. Farm size and fertilizer use were both significant in accounting for variations in the yield as well. The slopes of the wheat fields were not found to be significant in explaining variations in yields within the study area.

Implications for Development

For wheat production to increase in Ecuador in general and within the study area in particular, there are various changes which must be made. The encouragement of more agriculturalists to enter wheat production is of the utmost importance. Incentives in terms of a reasonable monetary return to the factors of production for the wheat producers is of primary importance. An upward evaluation of the basic controlled price of wheat is necessary within the domestic market, at least to keep pace with the rate of inflation in Ecuador. The formation of a good extension program is also necessary to introduce all wheat producers to the benefits of using certified seed, the correct type and amounts of fertilizer, and the use of machinery. At least partial mechanization of wheat production would be useful in terms of increasing yields.

In conjunction with this extension work there is a definite need for the expansion of the availability of agricultural credit. This is necessary not only in terms of machinery use, but also for the successful introduction of biological inputs. In reference to both agricultural extension and credit, there must be a serious attempt by the agencies involved to reach all wheat producers within the study area, large and small alike.

Mechanization has proven to be an important consideration with respect to wheat yields within the study area. Its use in conjunction with fertilizer application would, therefore, seem to be a means of increasing wheat production. There is a limit to the degree to which farm mechanization can take place in the study area. This is because slope has been shown to adversely affect machinery use within Pichincha Province. It should be pointed out, however, that a majority of this area's wheat producers could introduce some or more mechanization to their wheat cultivation. An example of this is the seeding and fertilizing stage, where only thirty-one of the area's wheat producers use mechanical means at present. With correct seed drilling and even fertilizer spreading, the mechanization of this stage could substantially increase yields.

With the exception of one of the problems of using machinery in this area, steep and irregular land, the other three problems could be solved to the benefit of the entire country. Machinery parts could be made more readily available and at a lower cost (as has been done with the fertilizer industry in Ecuador) by the establishment of a domestic industry to produce these commodities. This would benefit the industrial sector through the creation of additional employment. Through the establishment of more part outlets in conjunction with repair facilities, jobs in the service sector could be created within the rural areas of Ecuador. At the same time this would alleviate two of the problems encountered by machinery users.

More widespread availability of agricultural credit would allow more producers to use machinery in their crop production. Ideally, Ecuador should establish their own machine manufacturing industries, creating additional employment, as well as lowering machinery costs. In the wake of the recent oil discoveries in Ecuador, this solution is highly possible. Through the domestic production of these and other farm input materials, the surplus labor in the urban and rural areas would gradually diminish.

Implications for Future Research

This study of the mechanization of wheat production in Pichincha Province, Ecuador has suggested a number of possible lines for future research. In general, the study of agricultural mechanization in Ecuador is far from complete, as this study applies only to the production of wheat in one area. Wheat in itself is the most mechanized crop within Ecuador at present, and different problems would seem likely to exist in the mechanization of other crops.

The labor displacing effects upon Ecuador's economy, caused by hasty mechanization through the importation of machinery, is a broad study in itself, but one which would be extremely worthwhile. This would have to be analyzed in terms of the possible growth in agriculturally related services and industries.

The study of machinery hiring services in rural Ecuador would also seem to be of the greatest importance. These services have evolved out of the private sector in Ecuador and there would be many facets of this variable which would be of importance in terms of the mechanization of agriculture in Ecuador.

In terms of machinery use and wheat production considered together, it is felt that the effects of climate, soils, hydrology, seed, and fertilizer use need to be considered in detail, particularly regarding wheat production on the slopes of the Andes Mountains. It is important not only in terms of wheat production, but within the context of agricultural mechanization itself. The effects of machinery use on yields must be determined to a finer point, with these factors brought into the analysis.

Conclusion

In summation it would seem that the topography in Cantons Mejia, Quito, and Ruminahui were of the greatest significance in determining the present level of agricultural mechanization in Pichincha Province. The use of agricultural machinery in this area is, however, quite substantial, considering the problems experienced using it. It has been shown that the use of machinery causes differences in the yields obtained, in comparison to the non-mechanized production. It must be remembered though that mechanization of wheat production will not cause production increases by itself. There is a fundamental need for the expansion of agricultural credit and increased distribution of it in order to purchase agricultural machinery, and to increase the use of other agricultural inputs. The use of agricultural machinery in conjunction with the use of better seed, fertilizer, and improved cultural practices in general, will substantially affect wheat production in Pichincha Province, Ecuador.

APPENDIX A

Questionnaire

I. Location
   1) Canton ____________.
   2) Parrish ____________.
   3) What is the town nearest to your farm? ____________.
      a) How many kilometers is it from your farm? ____________.
   4) How many kilometers is it to the canton capital from your farm? ____________.
   5) How many kilometers is Quito from your farm? ____________.

II. Farm Size
   1) What are the number of hectares in your farm? ____________.
   2) How many hectares do you have sown in wheat? ____________.
   3) How many hectares are sown in crops other than wheat? ____________.
   4) Percentage cultivated ____________.

III. Slope, Yields, Fertilizer Use
   1) How many quintals of wheat do you harvest per hectare? ____________.
   2) How many quintals of fertilizer do you use per hectare of wheat? ____________.
   3) Slope of wheat field ____________.

IV. Machinery Use
   A. Do you use machinery in your wheat cultivation?
      Yes ____________. No ____________.

   1) What types of machinery do you use?
   2) What implements do you use?
   3) What is the horse power of your tractor?

Type	Horsepower	Implements
____________	____________	____________
____________	____________	____________
____________	____________	____________

B. How do you prepare the land for wheat sowing?
__________.

1) Machinery.
   a) Do you own or rent it? __________.
   b) What is your total cost for using machinery to prepared your land per hectare?
   __________.

2) Other
   a) Do you own or rent this equipment?
   __________.
   b) What are your total costs for preparing each hectare of land by this method?
   __________.

C. How do you seed and fertilize your wheat fields?
__________.

1) Machinery.
   a) Do you own or rent it? __________.
   b) What are your total costs of using machinery to seed and fertilize per hectare?
   __________.

2) Other.
   a) How many paid men do you hire to seed and fertilize your fields per hectare? __________.
   b) What are your total costs of seeding and fertilizing your land by this method for each hectare? __________.

D. How do you harvest your wheat crop? __________.

1. Machinery.
   a) Do you own or rent your combine? __________.
   b) What are your total harvest costs using machinery per quintal of wheat harvested?
   __________.

2. Manual harvest - threshing machine.
   a) How many paid men do you hire to harvest each hectare of wheat? __________.
   b) Do you own or rent your threshing machine?
   __________.
   c) What are your total harvest costs per quintal of wheat harvested by this method? __________.

3. Manual harvest - animal threshing.
   a) How many paid men do you hire to harvest each hectare of wheat? __________.
   b) Do you own or rent the animal you use for threshing? __________.
   c) What are your total harvest costs per quintal by this method? __________.

E. Do you hire a machine operator? Yes __________.
No __________.

V. Problems.

1) What problems do you encounter in using machinery in your farming? __________.
__________.

2) Why do you not use machinery in all stages of your wheat cultivation? __________.
__________.

3) Why do you not use machinery at all for your wheat cultivation? __________.
__________.

APPENDIX B

Summary Table of Stepwise Multiple Regression of the Dependent Level of Mechanization[1]

		Variables Included						Variables Excluded	
Step	Var.[2]	Mul.R.	Std.Err.	R^2	Increase	Reg.Coiff.	Std.Err.	Var.[2]	Part.R
1	X_1	0.77135*	0.92767	0.59499*	0.59499*	-0.77135*	0.01130	X_2	0.08706
								X_3	-0.15106
								X_4	0.04292
								X_5	0.24920
								X_6	0.22337
								X_7	0.30737
2	X_7	0.79577*	0.88598	0.63325*	0.03826*	b_1=-0.72807*	0.01106	X_2	0.10554
						b_7= 0.20034*	0.00212	X_3	-0.10978
								X_4	0.03474
								X_5	0.11347
								X_6	0.15961
3	X_6	0.80162*	0.87783	0.64259*	0.00934*	b_1=-0.70117*	0.01135	X_2	0.07082
						b_7= 0.17500*	0.00217	X_3	-0.13529
						b_6= 0.10490*	0.00029	X_4	0.03148
								X_5	-0.09857
4	X_3	0.80569*	0.87297	0.64914*	0.00654*	b_1--0.65659*	0.01272	X_2	0.08259

(Continued)

				Variables Included				Variables Excluded	
Step	Var.[2]	Mul.R.	Std.Err.	R^2	Increase	Reg.Coiff.	Std.Err.	Var.[2]	Part.R
4 (continued)						b_7= 0.15879*	0.00219	X_4	0.18944
						b_6= 0.11737*	0.00029	X_5	-0.08589
5	X_4	0.81347*	0.86036	0.66173*	0.01259*	b_1=-0.62946*	0.01279	X_2	0.12382
						b_7= 0.13080*	0.00222	X_5	-0.08685
						b_6= 0.13148*	0.00029		
						b_3=-0.23041*	0.00734		
						b_4= 0.16668*	0.00721		
6	X_2	0.81665*	0.85694	0.66691*	0.00519[+]	b_1=-0.61655*	0.01288	X_5	-0.11174
						b_7= 0.13412*	0.00221		
						b_6= 0.11480*	0.00029		
						b_3=-0.25450*	0.00741		
						b_4= 0.18779*	0.00732		
						b_2= 0.07656	0.02136		
7	X_5	0.81919*	0.85479	0.67107*	0.00416[+]	b_1= 0.20150*	0.00304		
						b_7= 0.20150*	0.00304		
						b_6= 0.29482*	0.00078		
						b_3=-0.25032*	0.00744		

(continued)

	Variables Included						Variables Excluded	
Step Var.[2]	Mul.R.	Std.Err.	R^2	Increase	Reg.Coiff.	Std.Err.	Var.[2]	Part.R
7 (continued)					$b_4 = 0.19093^*$	0.00730		
					$b_2 = 0.08907^+$	0.02166		
					$b_5 = -0.21936^{\neq}$	0.00061		

*= significant at 0.01 level.
+= significant at 0.05 level.
≠= not significant.

1. Final Regression Equation:

$$X_o = 3.1138 + (-)\ 0.6072X_1 + 0.2015X_7 + 0.2948X_6 + (-)\ 0.2503X_3 + 0.1909X_4 + 0.0891X_2.$$

2. X_1 Slope of Wheat Field.
   X_2 Distance to Nearest Town.
   X_3 Distance to Canton Capital.
   X_4 Distance to Quito.
   X_5 Farm Size.
   X_6 Hectares in Crop.
   X_7 Hectares in Wheat.

APPENDIX C

Summary Table of Stepwise Multiple Regression of the Dependent Variable Yields[1]

Step	Var.[2]	Mul.R.	Std.Err.	R^2	Increase	Reg.Coiff.	Std.Err.	Var.[2]	Part.R.
1	X_1	0.60069*	14.16689	0.36083*	0.36083*	b_1= 0.60069*	0.85559	X_2 X_3 X_4	0.13974 0.03697 0.24311
2	X_4	0.63135*	13.79191	0.39861*	0.03778*	b_1= 0.44494*	1.06783	X_2 X_3	0.15218 0.01920
3	X_2	0.64229*	13.68130	0.41253*	0.01393^{+}	b_1= 0.39552* b_4= 0.25392* b_2= 0.12687^{+}	1.11391 0.62735 0.00309	X_3	0.01132
4	X_3	0.64235*	13.73100	0.41261*	0.00008$^{\neq}$	b_1= 0.40870* b_4= 0.25306* b_2= 0.12636^{+} b_3= 0.01521$^{\neq}$			

*= significant at 0.01 level.
+= significant at 0.05 level.
≠= not significant.

(continued)

1. Final Regression Equation:

$$X_Q = 6.57751 + 0.40870X_1 + 0.25306X_4 + 0.12636X_2.$$

2. X_1 = Level of mechanization.

   X_2 = Farm size.

   [illegible] = Slope of wheat field.

   [illegible] = Fertilizer used.

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