Labor Requirements and the Effects of Mechanization on Labor Efficiency in the Hamiota Area

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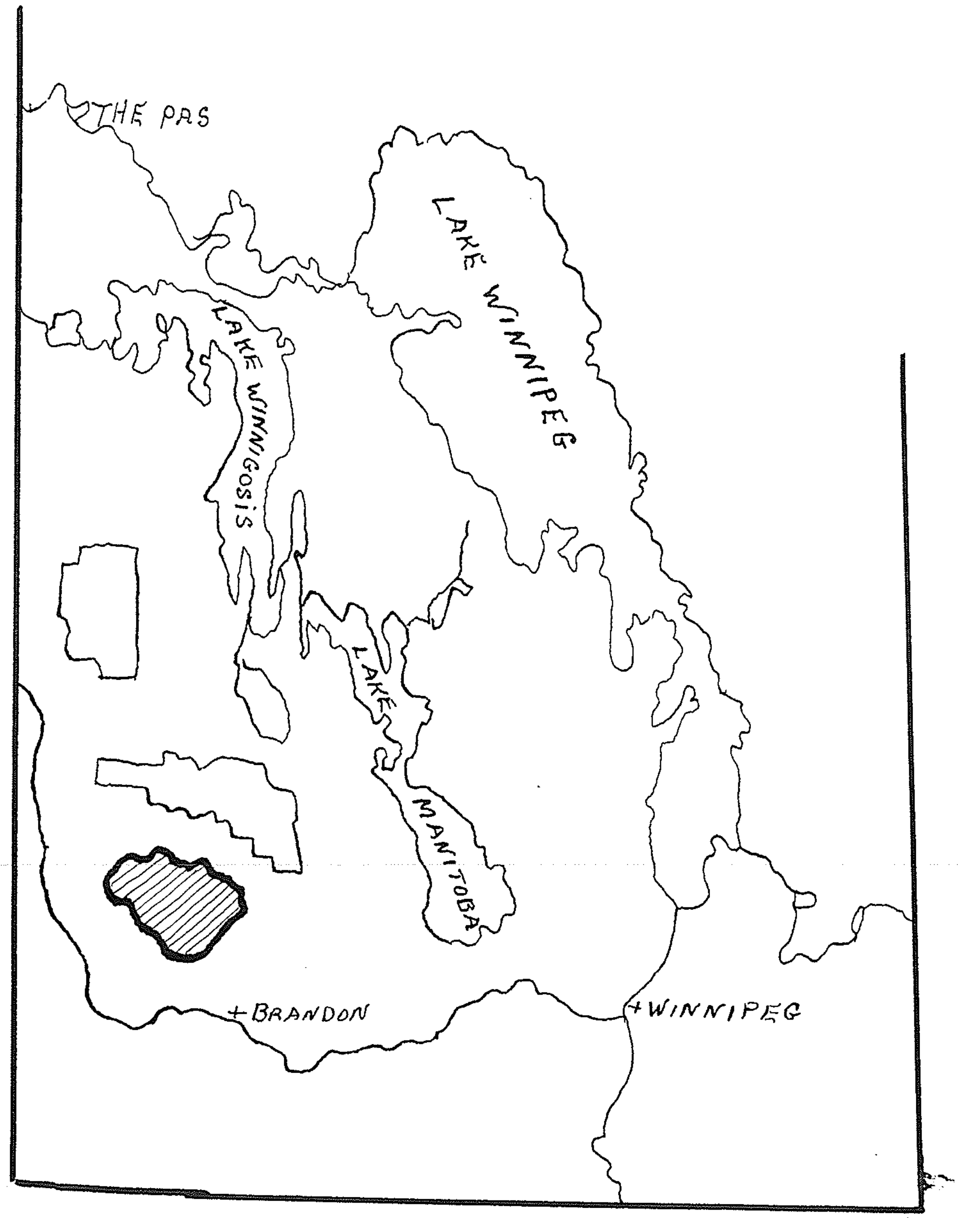

HAMIOTA AREA

MAP OF MANITOBA

LABOR REQUIREMENTS AND THE EFFECTS OF MECHANIZATION ON LABOR EFFICIENCY IN CROP PRODUCTION IN THE HAMIOTA AREA

CHAPTER I

INTRODUCTION

Labor as a productive resource is scarce and costly. Any technique or method of production which increases labor efficiency in crop production clearly influences not only the agricultural industry but our whole society. Mechanization of crop production especially since the advent of the rubber-tired tractor, self-propelled combine and motor truck has indeed created a revolution within agriculture; it has permitted in a major way, the general transfer of labor resources from the farm to the urban economy.

Crop production involves the use of various inputs. These inputs are known as factors of production. They include such elements as labor, machinery and land. The production process may be organized in several ways. By using more machinery less labor is involved per unit of output. Accompanying the movement of the substitution of machinery for labor in crop production has been the trend towards a larger size of farm unit. The farm entrepreneur must select from the many different alternatives that organization which pays best. What pays best at any given time depends upon the response in physical output to the changes in the production process and upon the changing prices of the various inputs in relation to one another and to the price of the output. Therefore, in actual production the farmer and researcher are confronted constantly with the problem: How much labour and how much machinery will give the optimum combination? What is the economic size of farm unit in relation to the desirable size of crop machinery?

Numerous vitally important production problems which exist on the farm cannot be solved by ordinary observation and experience. Input-output research is necessary if guidance is to be offered on efficient farm resource allocation. A farmer may claim that larger machines are necessary in order to compensate for the high cost and scarcity of labor. Another is convinced that two smaller machines of a certain type are more desirable than one large machine in certain operations of crop production.

Some of the many problems cited, imply the need for both technical and economic analyses. It is only through integration of physical input-output relationships in crop production with the associated price-cost relationships that any attempt can be made to set out what is economic from the point of view of an income maximizing farm firm. Input-output information will enable producers to select the most economic practices under both changing physical and price relationships.

The one purpose then of input-output research in crop production is to provide more accurate and complete basic knowledge on the existing relationships between labour, mechanization and size of farm. It should seek to isolate the possible consequences of changing physical production practices. With complete knowledge of physical input-output relationships, one can then proceed to apply prices and costs in the attempt to establish the economic aspects of crop production.

This study is interested only in one phase of the physical input-output data of crop production. It will reveal the effects on the required amounts of labor as size of machinery is increased. An analysis will also be carried out on the relationship between size of farm and size of machinery.

A. Objectives

The task of this study will be to determine the amount of labor required to produce an acre of crop under certain given conditions. This will involve besides the determination of crop labor requirements, an analysis of the effects of mechanization on labor efficiency and the difference in labor requirements as size of farm varies. The objectives are specifically these:

1. To determine the amount of labor involved in crop production on a given type of farm organization.
2. To establish the substitutionary relationship between labor and machinery on these farms.
3. To evaluate the efficiency of labor use in crop production on these farms.

B. Source of Material

The data for this report has been drawn almost wholly from weekly reports submitted by farmer-cooperators who agreed to keep a tabulation on the functional use of labor in crop production throughout the crop season. References have also been made to other similar studies, publications and bulletins which will be noted throughout the analysis of the study.

C. Scope of the Study and Characteristics of the Area of Study

1. Location and extent

The area covered by the study is a region in western Manitoba comprising a block of land approximately 42 miles long and 30 miles wide. This area which generally surrounds the town of Hamiota, is situated between the Riding Mountain National Park to the north and the city of Brandon to the south.

2. Climate

The climate of this area is conducive to a mixed-farming type of organization.[1/] The area is well adapted to the growing of the common cereal crops of Manitoba. The area is also suitable to extensive livestock production. There is a frost free period of 110 to 115 days. The annual precipitation is 16 to 17 inches. Generally, about half of the precipitation falls in the months of August, September and October. The year in which this study was carried out was characterized by adverse weather conditions which prevailed during a large part of the harvest period. This will have had an abnormal effect on the labor efficiency and labor requirements of the crop harvesting season.

1/ Much of the information pertaining to the climate of this area was taken from the following unpublished report: Riecken T.O. A Farm Business Study in the Hamiota Area of Manitoba. Economics Division, Marketing Service, Canada Dept. of Agriculture, 1948. p. 2.

3. Physical characteristics of the area

The soils of this area are the northern black earths of the Newdale Association. The soils are very fertile and of clay-loam texture. They are described as follows: "Northern black earth soils developed on glacial till under intermixed prairie and aspen woods. Topography is undulating with occasional to numerous sloughs or undrained depressions".[2/] The numerous sloughs and undrained depressions have had a marked effect on the field patterns of this area, which are characterized by very irregular shapes. It is suggested that such irregular-shaped fields have had a decided effect on the operating efficiency of field machines and hence on labor requirements in crop production. However, no deliberate attempt was made in the present work to evaluate the effects of such a factor.

4. Time period of the study

The study comprises an entire crop season from April 1, 1951 until freeze-up in the fall of the same year.

D. Methods

The techniques and procedures used in any research project of this kind are vital in determining the validity of the results.[3/]

2/Land Classification Map, Rossburn Area of Manitoba, Manitoba Soil Survey, University of Manitoba, 1940.

3/Many writers are aware of the need for a more rigorous methodology in economic research. For a more exhaustive treatment see: (a) Heady E.O., "Implications of Particular Economics in Agricultural Economic Methodology". Journal of Farm Economics, Nov. Proceedings, 1949. pp 837-850. (b) Salter, L.A., A Critical Review of Research in Land Economics, University of Minnesota Press, 1948, Chap. III.

Accordingly, great care must be exercised in the selection of appropriate methods of study of any problem. Each problem of a study has its own appropriate methods of inquiry and analysis. In view of this, emphasis was placed in this study on the adoption of those methods which would prove most effective in resolving the particular problem of labor requirements, labor efficiency, and the substitutionary relationship between labor and mechanization in crop production.

1. Method of survey and collection of the data

The field survey method in combination with mailed reports was used to obtain the information embodied in this report. In the preliminary field survey which had the objective of contacting and selecting a given number of farmers who would be cooperators in this study, no formal random selection technique was employed. In view of this, some limitations will be imposed on the generalizations made from the findings of this work. The initial selection method used, was one of selecting a given number of farmers from each of three groups of farms stratified on the basis of total assessed acreage. The three groups of farms were those of one-half, three-quarters and one section sizes. Only those farms qualifying for one of any of the three size groups and which had less than one-half mile between any of the respective quarter sections comprising a farm unit, were acceptable as farms for this study. All the farms selected were from a single soil type.[4]

[4] The soil type on which the farms were located is known as the northern black earths of the Newdale Association. For a more complete account of the soil type see page 5.

There were 82 farms in the original sample taken in the Hamiota area. A variety of reasons such as sickness, pressure of other work, lack of interest etc. caused 18 of the original farm cooperators to discontinue before completion of the study. This meant that the data from 82 farms were available for analysis of the seeding season, with only 64 farms reporting data for the harvest season.

Three field calls were made at various times during the summer. The initial call served to organize and set up the study. Appropriate labor-report schedules and self-addressed envelopes were left with the cooperators at that time with instructions to mail in every week, (ending Saturday night) an account of the past week's labor expended in any way on crop production. A second call was paid to the cooperators during July. This call served two purposes: to gather additional information on land utilization, machinery and other data needed to supplement that of the weekly reports and also to bring the labor report of the delinquent respondents up to date. A third visit to the cooperators last thing in the fall helped bring the field survey to completion.

It was also decided that any respondents who were delinquent for any period exceeding two weeks during the crop season would have a letter mailed to them prompting their attention to the lag in their weekly reports. The effectiveness of this technique was questionable.

The purpose of the field calls and the correspondence with the cooperators was to keep the data as reliable as possible and to retain the maximum number of initial cooperators.

2. Methods of analysis and treatment of the data

a. Empirical: The empirical analysis employed in this study was oriented by the needs of the objectives outlined above. Accordingly, the farms were stratified by size based on assessed acreage of the farm unit. Within each size group or stratification, calculations were made to determine the labor input in the production of the various crops.

The evaluation of labor efficiency in crop production, and the determination of the substitutionary relationship between labor and machinery was based on comparisons made between the respective size stratifications.

b. Theoretical: The theoretical analysis of this study was guided by the need for analytical tools to explain and to give expression to the various tendencies inherent in the data of the study. Thus the theoretical treatment of the data centred around labor efficiency and the scale of the firm, labor efficiency in its relationship to mechanization, and the factors indirectly affecting labor efficiency.

3. Techniques used in processing the data

a. Allocation of summerfallow work to crop: Ordinarily there would be no problem in the allocation of summerfallow work to crops for crops grown on summerfallow would be charged with the labor and tractor work involved in working the summerfallow in the year proceeding the first crop year. As this study is limited to only one crop season, there is no account of work on summerfallow in the preceding year.

It was decided in light of this lack of information to record the work done on the summerfallow in the year of the study. Accordingly, the rate of summerfallow work thus recorded, was charged concurrently to only those crops which were grown on summerfallow from the preceding year.

It was felt that the magnitude of the labor, and tractor hours expended on the current year's summerfallow would not differ significantly from that of the preceding year.

b. The problem of fall work: Unfortunately, due to the adverse weather conditions which have prevailed for the last two years in this area during the harvest period, little or no fall work has been done. In the majority of years it is normal to work the stubble land in the fall, in preparation for a crop in the following year. This study takes no account of such fall work and in one respect might be considered as weak at this one point of analysis. However, it is believed that this lack of information would not underestimate the amount of work involved in crop production. It was expressed by most of the cooperators of this study that the absence of fall work in crop production was offset by the need for a greater amount of work on the land in the following year both for the spring work and the summerfallow. It is thus believed that there were certain compensating features which will allow the results of this study to reflect the labor needed in crop production of more normal years.

c. Allocation of labor not directly attributable to any specific crop: In crop production on any individual farm there is always labor involved in machinery repair, stone picking, granary repair etc. that is not directly related to any specific crop but which must be accounted for in estimating the total labor requirements for the production of individual crops. In this study such labor will be referred to as the overhead labor of crop production. This overhead labor was allocated proportionately to the individual crops on the basis of the seeded acreage of each of the crops in the year of the study.

CHAPTER II

THEORETICAL RELATIONSHIPS BETWEEN SCALE OF THE FIRM AND LABOR EFFICIENCY

The purpose of this chapter is to provide a theoretical background to guide the empirical analysis on labor efficiency and the scale of the firm, and the substitutionary relationship between labor and machinery in crop production. In order to construct the theoretical background relevant to this study it is necessary to resort to the theory of the firm. The relevant theory will involve a brief discussion of the economies of scale, and the substitutability of machinery for labor in crop production.

A. The Theory of the Firm

The firm may be defined as the fundamental unit in any sphere of economic activity. It is an individual business unit motivated to activity by the desire to maximize some end or ends. The ends may consist of innumerable types of satisfaction such as the desire to maximize profit, prestige, leisure or any other tangible or psychological satisfaction which the firm may consider worth striving for. In pursuit of any one of a number of objectives, the business unit must concern itself with the problem of what to produce and how to produce it once the choice is made. The firm must mobilize the resources of land, labor and capital in order to begin production. Within the framework of the firm decisions are made on the coordination of the various amounts of productive factors in a way to maximize any given end with a minimum expenditure of money, time, material or human effort.

There will be a given organization of the productive factors on a farm firm at any particular time. If the farmer had perfect knowledge of future events when he made his decisions, then the existing organization could be assumed to be compatible with a maximization of the end which the farmer set out as his goal; the farm organization may be considered as in a condition of equilibrium.1/ In practical terms such a farm would have an optimum combination of land, labor and capital.

However, the invariable situation is one where the farmer lacks perfect knowledge of the future. Frequent consequences must inevitably be the use of resources according to an anachronistic plan or decision. This means that on any farm at a particular time the combination of land, labor and capital may be far from the optimum. It is the responsibility of the farmer to plan and coordinate his use of resources in a way consistent with a maximization of the end he has in view.

The purpose of this brief discussion on the theory of the firm is to open the way for the analysis of the empirical data on the relationships between labor, mechanization and size of farm in crop production.

B. Labor Efficiency and the Scale of the Firm

The theory of the scale of the firm as it relates to labor efficiency is important in the present study because of the effects of

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1/ If the farmer had the maximization of income as his goal, then his farm organization would be in equilibrium when the marginal physical products of all the productive services are proportional to their prices. For a more detailed discussion of this principle, see: Stigler, G.J., The Theory of Price, the MacMillan Co., New York, 1947. pp. 177-178.

the scale of the farm firm on mechanization in crop production. This section is set out with the view of providing a theoretical framework within which one may analyze the factors inherent in the size of farm which have a direct relationship with mechanization in crop production. An analysis of the theory of scale must set out two concepts for consideration: (1) law of variable proportions or the short run view of the fixed size of plant and (2) the law of returns to scale, a long run view of the size of plant.

Returns to a firm may vary with output. It is influenced by (1) size or scale of plant (2) and the rate of utilization of the existing plant. A firm may be built to a certain size or scale and once having been organized into a certain size unit, it may utilize various proportions of its potential capacity. In effect, variations in either scale or rate of utilization of an existing plant will cause variations in the efficiency of labor use in the firm.

1. Short-run aspect of scale

The short-run aspect of scale is formally known as the law of variable proportions.2/ This law concerns itself with the behaviour of the total output of a firm when only one productive factor is varied in quantity.

One of the pertinent questions that may be posed in the present study is: What would happen to the operating effectiveness of a certain

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2/ See: Ibid. p. 116. Stigler defines the law of variable proportions as follows: "If the quantity of one productive service is increased by equal increments, the quantities of the other factors remaining fixed, the resulting increments of product will decrease after a certain point."

type of machine, if the size of this machine is increased on a given size of farm? It is generally postulated that diminishing returns would eventually occur because the increasing proportion of the variable factor to the fixed factor results in a combination that becomes less and less effective. Is there any theoretical evidence for this assumption in regard to increasing machine size relative to size of farm? It appears from general observation that there may exist considerable variation in the size of machine when applied to a fixed size of farm before any significant variation occurs in the operating effectiveness of a machine. It does appear though, that there are limits to the range of machine sizes which may be operated efficiently on a given size of farm. The combine-harvestor will be cited as an example. It seems logical to suppose that the size of combine will be limited by the size of field on which it operates. The manoeuvrability and hence operating effectiveness of an extremely large combine will be severely hampered on a very small field. From this it follows that each size of farm is best adapted to a certain size of machine. (This assumes a direct relationship between size of farm and size of field)

It follows from the argument on relationship between size of farm and size of machinery, that there should then exist a relationship between labor requirements and scale of farms. In other words, one could find variations in the labor requirements on a given size of farm simply because machinery size varied.

2. Long-run aspect of scale

The long-run aspect of the theory of scale is known as the law of return to scale. This law is based on the assumption that there are no fixed factors of production - all productive factors are freely variable as output of the firm is increased.

The discussion on the long-run aspect of scale is adopted here with the purpose of explaining the relationship between labor efficiency and the size of farm. The main problem to be considered here is the one of why labor efficiency is associated with increasing size of farm. Two major determinants of labor efficiency deserve some discussion: one being the direct effect of size of farm on labor requirements in crop production and the other being the indirect effect of size of farm on labor requirements because of the association of size of machinery with size of farm.[3]

Increased specialization of labor and machinery is associated with increased scale in industry. The efficiency of labor is greatly increased through the specialization of tasks performed by each worker. Less time is wasted in the non-productive work of moving from one task to another. Workers gain efficiency in physical output because of the repetitive nature of the task which each performs. The repetitive nature of each individual's work is associated with specialization of machinery.

3/ It will be noted subsequently that there is a direct correlation between size of farm and labor efficiency; also a correlation between size of farm and size of machinery. For an explanation of this see pp. 66-68 on the multiple regression analysis.

The specialization of labor and machinery is also true of crop production in agriculture but the specialization is not carried as far as in industry. With an increase in the scale of farm, it means that any single worker spends more time in productive work on the field and less time proportionately, in changing from one task to another. Overhead work such as repair and daily maintenance and repair of machinery constitutes proportionately less of the total labor involved in crop production as scale increases. The association between the management activity and direct productive work is unique to agriculture. The function of management and labor is usually carried on simultaneously by the individual entrepreneur of the farm firm. It seems quite probable as the scale of farm is increased, that the entrepreneur of the large farm spends more time relative to the entrepreneur of the small farm in management activity. In some cases on larger farms, management is entirely dissociated from actual productive field work when the entrepreneur acts wholly as a manager and hires labor to perform the field work. In pointing out the possible increase in specialization of labor and machinery as size of farm increases it will be suggested how scale of farm can have an effect on labor requirements in crop production apart from the factor of increased size of machinery.[4/]

4/It must be noted that while it is felt that increased specialization of labor and machinery does occur as scale of farm increases, no deliberate attempt was made in the present study to isolate the effects of this specialization on labor requirements in crop production.

C. Labor Efficiency and Mechanization

1. Substitutionary relationship between labor and machinery

When labor efficiency in crop production is measured in terms of labor input per acre of crop produced, it can be seen that any innovation which displaces labor can be regarded as contributing to labor efficiency. Mechanization, more than any other single technological development, has had a marked influence on increasing labor efficiency in crop production. A mechanical innovation is one which substitutes capital for labor.[5] It is the substitutionary relationship between capital and labor in crop production that one must keep in mind in order to understand why mechanization has contributed to labor efficiency.

Mechanization has displaced labor in two major ways: by direct substitution of a machine for hand labor and by speeding up the mechanical operations of certain processes in crop production. The increase in speed of mechanical operations or in the operating capacity of a machine is directly attributable to increased speed of travel or to increased width of machine. It can thus be readily seen that the most effective way of increasing labor efficiency in crop production is to increase the operating capacity of the machine which substitutes for hand labor or indirectly displaces labor by decreasing the time spent on an acre of crop.

5/For a more complete discussion of this see: Heady, E.O. "Basic Economic and Welfare Aspects of Farm Technological Advance", Journal of Farm Economics, May 1949. pp 296-297.

Mechanical efficiency means labor efficiency. The possibility of increasing labor efficiency by increasing the speed of travel of a machine is generally quite limited, due to the biological nature of agriculture. Mechanical efficiency can be increased through specialized machinery and through increased width of machine. A specialized machine such as the combine-harvestor combines several operations in one, thus reducing the time spent on an acre of crop production. Increased mechanical efficiency through extending the operating width of a machine has greatly increased labor efficiency but possibilities for further increases in labor efficiency through this method appear fairly limited. It is believed that diminishing returns quickly set in as the width exceeds a certain point. The increase in operating capacity of a machine is less than proportionate to increased increments of width when a machine attains a certain size because there is greater idle capacity when a machine is stopped due to field obstructions, mechanical breakdowns or is stopped for service and maintenance. This is not to state that future reductions in labor requirements will be severely checked because the possibilities of increasing the operating capacity of a machine are limited. It does mean that one can hardly expect as spectacular a reduction in crop labor requirements as has happened in the last half century.

2. Labor as an input resource

A man is more than a commodity. He is a strategic factor of production. His services are scarce and limited. In the earlier ages when capital equipment was limited mainly to comparatively simple tools, labor was the chief productive resource. As technology advanced capital as a factor of production became more and more important. Capital has substituted to a large degree for labor in many industries but even today labor as a productive resource remains indispensable.

a. Substitutable factor: When a technological innovation is adopted in an industry there will be a change in the proportions of the productive factors. It is not the concern of this study to understand why a mechanical innovation in crop production has tended to be of a capital-substituting nature[6/] (i.e. labor has been displaced by machinery) but it is important to observe that mechanization of crop production has tended to displace labor.

b. Cooperant factor: In some industries characterized by a strong elastic demand for their products, labor as a productive resource will act as a cooperant to a capital or mechanical innovation.[7/] In agriculture, however, due to the relatively inelastic demand for agricultural products, a mechanical innovation seldom encourages a greater use of labor. This means that the development of mechanization in crop production must inevitably be accompanied by a decline in the proportion of labor as a productive resource.

6/ For a technical explanation of why labor has been superseded by capital, see: Ibid. pp. 301-304.

7/ Labor and capital will be cooperants if the increase in output due to a capital innovation is accompanied by a use of both more capital and labor.

CHAPTER III

FARM ORGANIZATION, LABOR, AND MACHINERY DISTRIBUTION

A. Type of Farm Organization

For the area under study all the major natural and economic determinants of type of farming were generally similar from farm to farm. The type of farm organization is determined by the interaction of environment, production resources and economic conditions. These factors predetermine to a large degree, the type of organization that prevails on the individual farm, factors which in the long run will even overcome the preferences of the individual farmer.

The Hamiota area may be broadly described as a mixed or diversified farming area. However, it will be observed (Table I) that the total receipts from the wheat crop constitutes over one-third of the total cash receipts, with receipts from all crops constituting around 60 per cent of total cash receipts. The Hamiota area also lends itself to a fair degree of livestock production by virtue of the physical features which characterize this area. Much of the land surface is non-arable due to sloughs, low lying depressions subject to periodic flooding and general wasteland. This non-arable land is utilized to a large degree for livestock production.

TABLE I

Sources and Amounts of Receipts, Hamiota, 1947-48[a]

Source	Average per Farm	Percent of Cash Receipts
	$	%
Wheat	1,714	36.0
Oats and barley	918	19.3
Other crops	275	5.8
Cattle	545	11.5
Hogs	211	4.4
Horses, sheep and poultry	72	1.5
Farm produce	372	7.8
Equipment sales	167	3.5
Custom work	66	1.4
Previous year's crop	408	8.5
Other farm receipts	13	.3
Total Cash Receipts	4,761	100.0
Increase in inventory	1,845	
Receipts from non-farm sources	966	
Home consumed farm produce	363	

(a) This table was adopted from the following unpublished report: Reicken, T.O. A Farm Business Study in the Hamiota Area of Manitoba, Economics Division, Marketing Service, Canada Dept. of Agriculture, 1948. p. 20.

1. Land use

The area under study has fertile soils and the climatic and economic factors combine to form a favorable setting for crop production. Information gathered in this study indicates that for the 82 farms covered, 62 per cent of the assessed acreage of all the farms was under cultivation (Table II). This is due to the unfavorable topographical features of the area. For the entire group of farms there was an average of 300 acres classified as improved. Wheat occupies the dominant place among the crops grown with almost 28 per cent of the total improved acreage being devoted to that crop.

Barley and oats followed wheat as the next most important crops, constituting 16 and 15 per cent respectively of the total improved acreage. Flax as a crop in this area is subject to the widest variations. It was relatively unimportant in the year of the study, constituting only 5 per cent of the total improved acreage.

Almost one-third of the total improved acres was devoted to summerfallow. The high proportion of summerfallow in this area reflects the need for weed control and also to provide better land conditions for wheat production which constitutes the largest proportion of the crops grown on summerfallow. It is quite possible in the future with a more extensive application of weed spray that the proportion of summerfallow will decline in relative importance. Of the remaining acres devoted to other crops, improved hay and pasture played a relatively insignificant part in the land use program on this sample of farms.

The land use pattern as discerned by size of farms did not appear to vary greatly. Wheat, barley and summerfallow acreage was relatively constant throughout the different sizes of farms. The oat acreage showed a relative decline in acreage as size of farm increased with the flax acreage increasing somewhat as size of farm increased. It might be suggested from the general tendency for the proportion of the

TABLE II

Land Utilization by Size of Farm, 80 Farms, Hamiota 1951[a]

	½ Section		¾ Section		1 Section		All Farms	
	Acres	% of Improved Acreage	Acres	% of Improved Acreage	Acres	% of Improved Acreage	Acres	% of Improved Acreage
Total Improved	220	69.0	320	67	377	59	300	62
Wheat	53.6	24.4	95.8	29.7	109.3	28.8	83.1	27.7
Barley	36.8	16.7	49.9	15.4	63.7	16.8	48.2	16.1
Oats	39.4	17.9	52.2	16.2	44.2	11.6	45.5	15.2
Flax	9.6	4.5	10.4	3.1	29.2	7.6	14.5	4.8
Other	-	-	2.2	.6	.7	.2	1.0	.3
Summerfallow	74.2	33.7	103.1	32.1	121.4	32.1	96.5	32.2
Breaking	2.1	1.1	.6	.2	1.3	.3	1.3	.4
Improved Hay	2.1	1.1	7.4	2.2	7.8	2.1	5.5	1.8
Improved Pasture	1.0	.6	1.6	.5	2.0	.5	1.5	.5

(a) The data in this table are based on the present study.

oat crop to decline as size increased, that the oat crop as a feed crop was relatively more important as a source of feed for animals on the smaller farms.

2. Livestock distribution

The importance of livestock was of limited significance in the Hamiota area which is generally described as a diversified farming area. Only approximately 17 per cent of the total cash receipts were derived from direct livestock sales.[1] It might be suggested that this area is adapted to and has a potential for greater livestock production but various factors such as the shortage and high cost of labor, desire for leisure on the part of the farmer, dislike for the work attached to livestock production which does not lend itself to extensive mechanization, and various other incidental factors have all conspired to limit the number of livestock kept on the farms in this area.

The present number and usual number of livestock kept on the various sizes of farms is shown in Table III.[2]

The typical number of milk cows was around 3 to 4 head, with little evident variation in numbers as size of farm increased. There were surprisingly few cattle fed in the barns, described in Table III

1/See Table I, Sources and Amounts of Receipts, Hamiota, 1947-48 as adopted from the unpublished report: Riecken, T.O., A Farm Business Study in the Hamiota Area of Manitoba, Economics Division, Marketing Service, Canada Dept. of Agriculture, 1948. p. 20.

2/Note that "usual number" as used here means the average numbers kept in the last three to four years prior to the year of the present study.

TABLE III

Average Livestock Numbers per Farm by Size of Farm[a]

	½ Section Pres. No.	½ Section Usual No.	¾ Section Pres. No.	¾ Section Usual No.	1 Section Pres. No.	1 Section Usual No.	All Farms Pres. No.	All Farms Usual No.
Horses	2	2	2	2	3	3	2	2
Milk Cows	3	4	3	4	4	4	3	4
Cattle on Feed	1	1	1	1	1	2	1	1
Cattle on Pasture	7	9	9	10	20	18	11	12
Pigs								
Brood Stock	1	1	1	1	1	1	1	1
Hogs on Feed	7	7	8	7	6	6	7	7
Poultry								
Young Stock	125	81	101	90	164	160	124	103
Old Stock	32	91	40	81	41	147	37	100

(a) The figures shown in this table are based on the data of the present study.

as cattle on feed. A greater number of cattle were retained on pasture. The number of cattle on pasture showed a significant increase in going from the three-quarter section to the one section size.

An average of one brood sow with approximately 6 to 8 feeder pigs was typical of most farms. Most farms preferred to raise only enough pigs to use up scraps and available skimmilk around the place. This meant that the farm's meat requirements were met with only a few pigs per farm available for commercial sale.

The poultry enterprise formed a minor enterprise on most farms, enough being kept for mainly home requirements. There were 32 to 41 old hens kept and around 101 to 164 young chickens at the time of the study. It is peculiar to note that the farmers indicated a usual number of hens exceeding by two or three times their present number.

Horses as a source of power in crop production were practically absent. Only one farm of the entire group used horses for seeding purposes. The chief importance of horses in crop production included use during the harvesting season if the threshing machine was used. While most farms retained from two to three horses, their chief significance rested on their use for farm chores, haying and for winter driving, although even the latter is becoming less important with roads being kept open most of the winter.

B. Labor Distribution and Relationship to Scale

1. Available labor

The average composition and amount of available labor according to size of farm is shown in Table IV. The amount of labor available is based on the number of male adults for the eight months of crop production (April to November inclusive). The total amount of available labor was expressed in terms of the man-equivalent of labor.[3/] In most cases the operator was present for most of the crop period.

[3/] A man-equivalent rating is based on the equivalent of eight male adult-months of labor. Each woman and each child (12 - 16 years) were given the rating of 1 adult-month of labor for the entire crop period if they participated in outside farm work during the crop season. For a more complete discussion on the man-equivalent of labor as used here see Technical Appendix, p.124.

The farm operator represents the permanent labor force as distinguished from the incidental help given by wives, school children

TABLE IV

Average Male Adult Months of Available Labor per Farm as Distributed by Size of Farm

	½ Section	¾ Section	1 Section
Months of Labor per Farm			
Average Male Adults	9.2	11.1	12.8
Average Female Adults	.5	.6	.3
School Children (12-16 years)	.3	.4	.4
Hired Labor	-	.3	1.1
Total Male Adult-Months	10.8	12.4	14.6
Average Man-Equivalents per farm (a)	1.25	1.55	1.82
Improved Acres per Man-Equivalent	176	206.4	207.1
% of Farms Reporting Exchange of Labor with Neighbors	50 %	28 %	27 %

(a) Legend for Man-Equivalent Conversion

8 Male Adult-Months = 1 Man-Equivalent
1 Female Adult = 1 Man-Equivalent Month
1 School Child (12-16 years) = 1 Man-Equivalent Month
The average man-equivalent per farm was calculated by dividing the total male adult months by eight.

or seasonal labor. The purpose of the man-equivalent rating was to be able to express the various qualities of labor in some comparable terms. Man-equivalent ratings of family labor do not adequately describe the actual contributions made by women and children on the farm. For some tasks which do not require heavy physical exertion, such as driving a tractor or truck, a boy of fourteen can be fully as effective as an adult. This is often typical of the case where father and young son work together. The son most often is given those tasks which he can do as well as any adult, thus releasing his father for other heavier and more complex work.

It will be noted (Table IV) that the total male adult months of available labor increased as size of farms increased. When the total male adult months were converted to man-equivalents, it will be seen that there was 1.25, 1.55 and 1.82 man-equivalents of available labor on the half-section, three-quarter section and one section farm sizes respectively. There was considerable exchange of labor among neighbors, with 50 per cent of the half-section groups, 28 per cent of the three-quarter section group and 27 per cent of the one section group respectively reporting exchange of labor with neighbors. This is significant because many of the farmers on the small size farms did not have enough work on their own farm to keep them occupied and hence were available part-time to the larger size farmers who needed extra labor at certain periods of the crop season.

When a comparison between different sizes of farms is based on the amount of improved acres per man-equivalent of available labor, there appears to be little significant increase in the amount of crop handled per man-equivalent as the size of farm increases.

It will be seen (Table IV) that a significantly small amount of hired labor was available on the group of farms studied. There was no hired labor reported on the half-section group during the eight months of the crop season. During the same period the three-quarter and one section group reported .3 and 1.1 months respectively of hired labor.

2. Labor requirements

This section will show and discuss the amount of labor used in crop production for the different seasons of the crop period. It will show the total number of hours used per farm for the different seasons in crop production. It will then compare the amount of labor used to the available labor by showing the number of hours used per man-equivalent of available labor.

It is to be observed that the total number of hours of labor per man-equivalent used for the seeding season is least on the three-quarter size farms (Table V). During the harvest season the numbers of hours spent per man-equivalent is again least on the middle size group of farms. For the entire crop year there appeared to be a slight increase in the total hours spent per man-equivalent as size of farm increased.

It is to be noted that a man-equivalent in the half-section group handled 176 improved acres[4] and the total hours required per man-equivalent to handle this acreage during the seeding season was

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[4] The number of improved acres handled per man-equivalent will be noted in Table IV. p. 27.

150.6 hours; a man-equivalent in the three-quarter group handled 206 improved acres and required 138.8 hours to handle this acreage;

TABLE V

Average Hours of Labor Used per Farm in Crop Production, by Tasks, for Man Labor and Tractor Labor

Task	½ Section Hrs./ Farm	½ Section Hrs./Man Equiv.*(a)	¾ Section Hrs./ Farm	¾ Section Hrs./Man Equiv.	1 Section Hrs./ Farm	1 Section Hrs./Man Equiv.
Seeding						
Man Hours	188.2	150.6	215.2	138.8	265.7	146.0
Tractor Hours	156.8	116.6	167.4	108.0	203.9	112.0
Harvest						
Man Hours	262.3	209.8	306.5	197.2	364.0	200.0
Tractor Hours	121.4	97.1	152.3	98.2	173.0	95.0
Entire Crop Year						
Man Hours	745.1	596.1	948.2	611.7	1189.4	653.5
Tractor Hours	433.1	346.5	569.5	361.0	723.8	397.9

* Equiv. denotes Equivalent

(a) The total required hours per man-equivalent was calculated by dividing the total hours used per farm by the corresponding man-equivalent of available labor per farm as established in Table IV.

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a man-equivalent in the one section group handled 207 improved acres and required 146 hours per man-equivalent to handle this acreage during the seeding season. The same tendency was noted for the harvesting season. The conclusion that can be drawn here is that while the man-equivalent in the half-section group handled less acres than either the three-quarter or one section group, it required more hours of labor per man-equivalent to handle the smaller acreage. Similarly, while the man-equivalents in both the three-quarter and one section group handled almost the same acreage the man-equivalent in the three-quarter group required considerably less hours to care for its acreage than in the case of the man-equivalent in the one section group.[5] This suggests for analysis in subsequent sections that, the effectiveness of labor on the three-quarter and one section size groups was greatly increased over that of the half-section group by virtue of greater mechanization per man.

C. Machinery Distribution and Relationship to Scale

The farms studied in the Hamiota area generally showed a high degree of mechanization. The proportion of investment in machinery as compared to the investment in total farm capital remained fairly constant as size of farm increased with the exception of farms well over one section in size. (Table VI)

The investment in machinery per man-equivalent in this area on the other hand showed marked variations among the different farm sizes and even within any given size group of farms.

5/To note how the hours spent per acre tend to decline from the half-section to the three-quarter section farms and then tend to rise again in moving from the three-quarter section to the one section farms, see Table XII page 50, Table XIII page 52 and Table XIV page 54.

TABLE VI

Average Machinery Investment, by Size of Farm in Hamiota, 1947-48[a]

Size	Machinery	% of Total Cap. Investment as Machinery Invest.	Total Capital Investment
Acres	$	%	$
up to 240	1686	25	6781
241-400	2869	25	11546
401-560	4721	26	18276
561-720	5271	26	20071
721 +	7759	29	26555

(a) This table was taken from the following unpublished report: Riecken, T.O., A Farm Business Study in the Hamiota Area of Manitoba, Economics Division, Canada Department of Agriculture, 1948. p. 16.

The variation in machinery per man-equivalent between farms is shown quite clearly by the data in Table VII; the intra-farm-size variation in machinery per man-equivalent is also quite significant. If the labor earnings shown in this table are any indication of the effectiveness of increased mechanization, then it can certainly be concluded that the larger farms, because they have larger machinery investments per man, will show up as more efficient than the small scale uneconomic units.

TABLE VII

Capital and Labor Efficiency According to Size of Farm, Hamiota, 1947-48[(a)]

	0-240		241-401		401 & over	
	Low Cap. Farms	High Cap. Farms	Low Cap. Farms	High Cap. Farms	Low Cap. Farms	High Cap. Farms
Farm Capital per man-equivalent	$8094	$11197	$11597	$14464	$12351	$18461
Machinery per man-equivalent	$1064	$ 2656	$ 2439	$ 3007	$ 2521	$ 5170
Acres of cropland per man-equivalent	146	148	186	212	231	285
Operator's labor earnings	$ 981	$ 726	$ 1854	$ 2246	$ 3024	$ 4133

(a) This table was taken from: Riecken, T.O., A Farm Business Study in the Hamiota Area of Manitoba, Economics Division, Canada Department of Agriculture, 1948. p. 40.

1. Intra-farm-size variation in size and type of machinery

a. General machinery: There appears to exist wide divergences in the size and type of machinery used on any given size of farm.

The data shown in Table VIII indicates a broad variation in the size and distribution of general machinery within any given size of farm. For example the six foot oneway seems most popular in the half-section group but the range in size of oneway used varies from six to nine feet. Within the half-section group of farms the size of cultivator used varies from eight to over fourteen feet. The size of harrows used in the half-section group varies from fourteen to

TABLE VIII

Size and Distribution of General Machinery by Size of Farm

Kind and Size	½ Section 24 Farms No.	½ Section 24 Farms %	¾ Section 25 Farms No.	¾ Section 25 Farms %	1 Section 15 Farms No.	1 Section 15 Farms %
Oneway						
6 feet	12	80	12	60	4	25
8 feet	2	13	7	35	10	63
9 feet	1	7	1	5	2	12
Cultivator						
8 feet	7	32	4	15	4	21
9 feet	2	9	-	-	1	5
10 feet	10	45	10	39	7	37
12 feet	2	9	8	30	3	16
14 +	1	5	4	16	4	21
Drag Harrows						
14-18 feet	6	26	5	18	1	7
19-22 feet	3	13	3	11	1	7
23-26 feet	10	43	10	38	5	33
26-30 feet	4	18	9	33	8	53

thirty feet.

Similarly within each of the two other size groups of farms there exists a wide range in the size of general machinery used.

b. Special machinery: As in the case for the general machinery it will be noted (Table IX) that for any given size of farm there exists a wide variation in the size of special machinery used. To take the half-section group of farms as an example, it will be observed that the tractor used varies from the 1-2 plow size to the 4-5 plow size; the drill varies from a 20 run to a 28 run; the combine size ranges from the 6 foot pull type to the 12 foot self-

TABLE IX

Size and Distribution of Special Machinery by Size of Farm

Kind and Size	½ Section 24 Farms No.	%	¾ Section 25 Farms No.	%	1 Section 15 Farms No.	%
Tractor						
1-2 plow	1	4	4	12	3	14
2 plow	3	12	2	6	2	10
2-3 plow	11	44	7	22	4	20
3 plow	1	4	2	6	-	-
3-4 plow	6	24	10	32	7	33
4-5 plow	3	12	7	22	5	23
Drill						
20 run	11	48	7	28	3	20
24 run	10	43	14	56	7	47
28 run	2	9	4	16	5	33
Combine						
6 foot pull type	10	50	6	26	7	46
8 foot pull type	4	20	7	30	-	-
10 foot pull type	-	-	-	-	-	-
12 foot pull type	2	10	3	14	2	14
10 foot self-propelled	1	5	-	-	1	7
12 foot self-propelled	3	15	7	30	5	33
Swather						
7-8 feet	4	21	1	4	2	13
9-10 feet	2	10	3	13	1	7
12 feet	12	63	18	75	10	66
14 feet	1	6	2	8	1	7
16 feet	-	-	-	-	1	7
Threshing Machine						
22 inch	6	60	3	25	3	38
24 inch	-	-	4	33	1	12
28 + inch	4	40	5	42	4	50

propelled type; the swather varies in size from 7 feet to 14 feet and the threshing machine from 22 inch to a 28 inch size.

This wide range of sizes of the different types of special machinery also occurs in each of the three-quarter and one-section size group of farms. However, the percentage distribution of the different sizes of machinery does suggest that there is usually one particular size of machine that is most common to any given size group of farms.

c. <u>General field observations on intra-farm-size variation in size of machinery</u>: While no deliberate attempt was made in the present study to isolate reasons for the wide range of machine sizes found on any particular size of farm, it will be useful to point out some of the observations made in the field in this respect.

One of the most important influences causing a wide range in size of machinery used on any given size of farm was that of labor. The scarcity, high cost and uncertainty of securing labor at critical periods on the farm, appears to have caused farmers in this area to have more machinery and larger machinery than would be suggested by the optimum combination.

Many farmers expressed their concern about the factor of timeliness of operations in the more critical periods of crop production. The frequent occurrence and the possibility of extremely adverse weather conditions during the critical periods and especially during harvest, has caused many farmers in this area to depend on reserve capacity in respect to machinery. The extreme case in the present study was a farm which had acquired an additional 12 foot self-propelled combine as a hedge against the bad harvest conditions which prevailed. This extra combine was used only four hours in the course of the harvest season. The latter case was not a representative situation but there were evidences of varying degrees of this reserve machine capacity in the area under study. It does suggest that the factor of timeliness exerts a strong influence on the amount and size of machinery retained on the individual farm unit.

Other farms showed a considerable variation in their size of machinery as a result of recent changes of ownership, changes in size of existing farm unit by acquisition of more land, and movement from one farm to another by farm renters. A few of the farmer-cooperators of this study had recently moved in from other areas. For example, a few farmers of the Hamiota area had recently moved in from the wheat plains of Saskatchewan; their case was almost invariably one of excess size of machinery in relation to their present farm. In other cases there was a divergence between existing size of machinery and that of the group average because of the recent acquisition of another parcel of land. These farmers did not have time to sell off their old machinery and purchase larger machines to suit their farm unit. Other farms appeared to have an excess size of machinery because they had purchased their present machinery with the anticipation of buying or renting additional land. Still other farms showed a divergence between their machinery size and the group average size because of the factor of custom services. It appeared that some of the farmers usually depended on hiring some of their work done - such farmers showed a lack of some machinery or an abnormally smaller size of machine. On the other hand some farmers bought excess size of machinery in relation to the size of their farm unit with the anticipation of performing custom services for neighboring farms.[6]

2. Inter-Farm-Size variation in size and type of machinery

There exists a significant difference in size and type of machinery as the size of farm varies.

a. Power: Power supply on the farms studied consisted almost entirely of rubber-tired tractors. As reported in the livestock section of this report, horses as a source of power were used sparingly. Their use was confined almost wholly to the harvesting season and only then when threshing machines were used to harvest part or all of the crop. Every farm reported one tractor, with 13 of the farms reporting two tractors. The 2-3 plow size tractor was found to be most popular on the half-section farms. The 3-4 plow tractor was most common to the three-quarter and one section farms, with the 4-5 plow tractor next most important on these two latter sizes of farms. It is important to note that power on these farms was supplemented to some extent by the use of self-propelled combines. One farm even reported the use of a self-propelled swather.

b. Tillage equipment: There was considerable variation in the size of the tillage equipment from farm to farm. The outstanding thing about the size of general equipment was that, contrary to expectations, some types of machinery were larger on the average on the

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6/Most of the explanations offered for variations in size of machinery within any given size group of farms have no empirical support in the present study but rather are observations made while gathering other data in the field work and through conversations with the various farmer-cooperators of this study.

TABLE X

Distribution and Average Size of Machinery by Size of Farm

Type of Machinery	½ Section 24 Farms No.	½ Section 24 Farms Average Size	¾ Section 25 Farms No.	¾ Section 25 Farms Average Size	1 Section 15 Farms No.	1 Section 15 Farms Average Size
Tractor (plow size)	25	1.9 plow	32	3.2 plow	22	3.1 plow
Plow	13	2.9 feet	12	2.8 feet	11	2.5 feet
One Way	21	5.9 feet	21	6.6 feet	16	7.5 feet
Drill	23	11.2 feet	25	11.8 feet	15	12.3 feet
Discs	11	9.6 feet	13	12.0 feet	5	11.8 feet
Discer	1	10.0 feet	6	10.3 feet	2	14.0 feet
Cultivator	23	9.6 feet	26	11.0 feet	19	10.6 feet
Spring Tooth Cultivator	12	11.7 feet	8	14.6 feet	5	16.2 feet
Drag Harrows	23	23.0 feet	27	24.0 feet	15	26.3 feet
Packer	5	15.8 feet	9	13.4 feet	9	11.2 feet
Rod Weeder	1	10.0 feet	1	10.0 feet	1	9.0 feet
Combine	20	8.1 feet	24	9.4 feet	15	9.3 feet
Swather	19	10.9 feet	24	11.8 feet	15	11.7 feet
Binder	17	7.6 feet	17	8.3 feet	13	8.4 feet
Thresher	10	24.2 inches	12	25.7 inches	8	25.2 inches
Truck	12	1 ton	16	1 ton	11	1.2 tons
Sprayer	6	30.7 feet	11	28.6 feet	8	30.7 feet
Overhead Fuel Tank	-		7		2	
Grain Loader	14		16		12	

three-quarter section farms than on the larger one section group of farms. The average size of the cultivator and discs was larger on the three-quarter size farms than on the one section group. All other general equipment and the seed drill appeared to increase in size as the size of farm increased.

c. Harvesting equipment: As in the case of the tillage equipment, considerable variation was evident in the size of harvesting equipment. On the average it was observed (Table X) that the three-quarter size farms showed larger combines and swathers than the one section group. While no attempt was made to isolate the reasons for this phenomenon, it is suspected that various factors are involved in giving the middle size group of farms the largest size machinery in some cases. Thirty farms reported threshing machines. While the combine remained the most common method of harvesting grain in this area, the traditional method of cutting grain with a binder and threshing the grain with a threshing machine was a typical method of harvesting a part of the oat crop on a large number of farms so as to have straw for animal feed.

d. Other equipment: The weed sprayer was becoming quite popular with 25 of the farms reporting ownership of spraying equipment. The mechanical grain loader, either in the form of a truck auger or as a portable granary auger was found on over two-thirds of the farms. Surprisingly few overhead tractor fuel tanks were reported. The installation of such tanks tends to reduce the amount of time spent in the daily fueling of the tractor. Many of the farms still use the old time-consuming and dirty method of pail and funnel as a way of refuelling the tractor.

CHAPTER IV

EMPIRICAL ANALYSIS OF THE STUDY

A. Calculation of Measurement Standards Used

1. Calculation of the criterion of labor efficiency

The analysis and definition of labor efficiency in crop production needs some criterion for the measurement of labor productivity. As this study is one concerned primarily with physical inputs and outputs (i.e. dollar measurements were precluded from the data gathered) of crop production, the criterion of labor efficiency must be in terms of some physical index; that is, the criterion will be essentially an expression of the technical coefficient of labor efficiency.

The criterion selected to measure labor efficiency in this work is expressed in terms of man-hours per acre of crop production. This means that the measurement criterion centres around the ratio of input measured in man-hours and the output measured in terms of the acres of crop produced.

As this study is interested in the substitutionary-relationship between labor and mechanization on the individual farm firm and the effect of mechanization on labor efficiency in crop production, the criterion selected for the measurement of labor efficiency has the advantage of being both specific and direct. Labor is the factor most significantly affected by mechanization in crop production; in general being displaced as mechanization develops.[1/] The measurement index of man-hours per acre will measure directly, the displacement

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1/See Heady, E.O. "Basic Economic and Welfare Aspects of Farm Technological Advance" Journal of Farm Economics, May 1949 p. 297 where he describes a mechanical innovation in agriculture as generally a labor saving innovation.

of labor as the scale of the farm and size of machinery increase. The criterion of labor efficiency used here also has the advantage of being a part of the more universal concept of economic progress or efficiency, when this concept is expressed as a minimization of the means relative to the ends produced.[2] The man-hours per acre measurement of labor efficiency is also compatible with the idea of economic progress being characterized by a paucity of labor resources in the subsistence goods industries.[3]

a. Some limitations of the criterion: Physical production per man-hour is not an ideal measurement of crop labor productivity. It is a ratio of total output per labor input. This ratio does not measure directly the actual contribution of labor as an input resource. Changes in the input-output ratio reflect the joint efforts of all productive factors which may affect either the labor input itself, other productive factors or even the output. Hence it is incorrect to attribute all of the changes in efficiency to farm labor. Changes in production per hour of labor must be interpreted in the light of changes in capital inputs and the other technological forces operating in crop production which affect mechanization or yields of the crop.

It has been suggested by one writer[4] that the use of a physical

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2/Boulding, K.E. Economic Analysis, Harper and Brothers Pub. New York, 1948. p. 647.

3/Ibid. p. 294

4/Davis, Hiram; The Industrial Study of Economic Progress, University of Pennsylvania Press, Phila., 1947. pp. 16-18. Davis discusses the use of various indexes to measure productive efficiency in industry.

index such as output per man-hour of input as a criterion of efficiency would not take immediate account of a process that would lower capital input for this same output, labor input remaining constant. Labor is the most important input in agricultural production however, and changes in the ratio of total production per unit labor of input does provide a useful measure of changes in efficiency of crop production.

2. Measurement standards for size of farm

a. Total assessed acreage: The farms were originally stratified into three size-groups for the purposes of the initial field survey. The three size-groups chosen were of one-half, three-quarters and one section sizes. The stratification by size of farm was based on total assessed acreage comprising the individual farm unit. The stratification by size of farm on the basis of the total assessed acreage of each farm unit was used most of the time in the analysis involving scale of farm.

b. Size based on total improved acreage: This standard involved the stratification of the farms under study, on the basis of the total improved acreage of each farm unit. The improved acreage included all current crop land, summerfallow, improved hay land and improved pasture land. This standard of size of farm was adopted because it was felt that the total assessed acreage did not necessarily reflect the extent of the improved acreage of the individual farm unit. It was believed that the size of machinery used on the respective farms would be more strongly influenced by the total improved acreage, than by the total assessed acreage. If any serious discrepancy had occurred between size of farm based on total assessed acreage and that of total improved acreage, any stratification by size of farm on the basis of assessed acreage would not have revealed a true relationship between scale of the farm and the size of machinery used. However, it was found in the course of the analysis that total improved acreage and total assessed acreage had a fairly close direct relationship.

3. Calculation of the index for aggregate size of machinery

In any attempt designed to establish the direct substitutionary-relationship between labor inputs and mechanization in crop production, there is a need for some method of expressing aggregate machinery size.[5] Merely to express machine size in linear feet is to ignore the complexity of the situation where size and importance of the various machines varies from farm to farm. Labor input per acre of crop production is influenced not only by the size of the various machines used in crop production but also by the relative importance of the various machines as expressed in terms of time used for each machine.

It will be the purpose of this section to set up an index which will give a common expression to the aggregate size of machinery used in crop production on any given farm. The index will reflect both the

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5/ See technical appendix for a more detailed explanation of this index pp. 120-122.

size and relative importance of each machine used. This will enable one to express the aggregate size of machinery used on each farm as an index. This index will then allow one to establish the relationship between size of farm, size of machinery used and labor efficiency as expressed in terms of labor input per acre of crop produced.

a. Steps involved in the calculation

(i) Frequency of operation: Labor input per acre can vary from farm to farm apart from the influence of size of machine used. If one farmer cultivates his land twice as much as the next farmer, then obviously his labor input will be twice as high. In view of this it was decided to determine whether frequency of operation varied significantly as between different sizes of farms.(Table XI) The frequency of operation of any particular machine used was calculated by dividing the acreage covered by the machine in question by the seeded acreage. The frequency of operation was calculated for all machines used within the three sizes of farms of this study. It was decided that the frequency of operation of all machines did not vary significantly between the different sizes of farms (see Table XI). With the assumption that cultural practices were generally uniform over the entire group of farms, it was decided that the size index of machinery would adequately reflect the relationship between size of machine and labor inputs per acre of crop.

TABLE XI

Frequency of the Different Operations for the Seeding Season

Stratification: By Size of Farm[a]

	½ Section	¾ Section	1 Section
Wheat			
Seed	1.00	1.00	1.00
Harrow	2.50	2.37	2.08
Cultivate	.82	.73	.84
Oneway	-	.01	.06
Disc	-	.14	.08
Spring Tooth	.17	.16	.01
Pack			
Barley			
Seed	1.00	1.00	1.00
Harrow	2.42	2.29	2.20
Cultivate	.92	.55	.83
Oneway	.37	.26	.27
Disc	.25	.26	.36
Spring Tooth	.09	.04	.11
Pack	.07	-	-
Oats			
Seed	1.00	1.00	1.00
Harrow	2.36	2.37	1.88
Cultivate	.98	.83	.98
Oneway	.26	.31	.19
Disc	.28	.51	.20
Spring Tooth	.02	.04	.14
Pack	-	-	-

(a) The frequency of any given type of operation was calculated by dividing the acreage covered by a given machine by the seeded acreage.
e.g. acreage covered = 200 acres
seeded acreage = 100 acres
frequency of operation = $\frac{200}{100}$ = 2.0

(ii) Establishment of a size base for each machine: There was need for some common base against which to relate the size of any given machine. The size base for each type of machine was calculated by finding the average size of each type of machine for the entire group of farms. (See technical appendix). The average size of each type of machine then, was used as the base-size against which to compute the size index of the same type of machine on the individual farm.

(iii) Determination of the relative importance of each machine: To determine the relative importance of each machine used on any given farm, it was necessary to find some system of weighting the machine so that its relative importance would be reflected in the aggregate machinery size index of the farm.

The weight for each machine was determined by calculating the percentage of time the machine was used as compared to the total time used by all machines.[6]

(iv) Calculation of the size index for a machine:

$$\frac{\text{Actual size of given machine expressed in feet}}{\text{Average size of the same type of machine}} \quad \text{X} \quad \text{weight number}$$

For example: Actual size of a given cultivator = 10 feet

Average size of the cultivator for all farms = 8

Size index = $\frac{10}{8} \times 20 = 25$

(v) Calculation of aggregate size index: The calculation of the aggregate machinery size index merely involved the summation of all the separate machine indices for the farm.

6/ Time used by a cultivator = 10 hours
Total time used by all other machines = 50 hours
Weight for the cultivator = $\frac{10}{50} \times 100 = 20$

If a given farm used machinery in the seeding season, the size of which was identical with average size of all machines for the entire group of farms, then its aggregate machinery size index would be equal to 100.

B. Labor Requirements in Crop Production by Seasons and by Size of Farm

Labor efficiency in crop production is especially significant when considered by seasons of the crop period. With a given labor force and a certain number of days prescribed by nature in which to accomplish the necessary work of any given season, labor efficiency becomes a crucial determinant in the optimum acreage handled. Timeliness of work in crop production is of supreme importance to crop yields. An increase in labor efficiency of crop production in any particular season, other conditions remaining constant, will allow an increase in the acreage that can be handled during that season. It can thus be seen that labor efficiency in crop production is the dominating factor in the determination of size of farm.[7] It is the hypothesis here that because the operations of the harvest season were relatively least mechanized that it is the labor requirements of that season that sets the upper limits to size of farm.[8] Assuming the validity of this hypoth-

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7/This assumes a given labor force and a specific number of days during the season in which the work must be accomplished. A given labor force is not too unrealistic when one considers that the typical farm depends heavily on family labor.

8/Throughout this discussion the term "least mechanized" means both lack of mechanization by tasks as well as less intensively mechanized from the point of view of the time period of the particular season under discussion. The same conditions apply to the term "more mechanized".

esis it follows that further increases in mechanization of the operations of the seeding season (given constant conditions of harvesting methods) will only add to the underemployment or leisure of the farmer during the seeding season. In other words with the present type of farm organization and with given methods of seeding and harvesting, it is suspected that farmers in this area under study, cannot safely harvest the maximum acreage which could be seeded, or on the other hand he can harvest the maximum acres which can be sown, only by increasing his labor force and/or machinery during the harvest season.

1. Seeding season

The labor involved in crop production during the seeding season included seed preparation, maintenance and service of the machinery, actual work in the field and any other tasks directly connected with the seeding season such as loading and hauling seed grain and handling of fertilizer. The actual work in the field included the seeding operations and all field preparations prior to and immediately following the seeding operations.

The labor and tractor hours per acre for specific crops for the seeding season are given in Table XII. The man-hours per acre include all those tasks named in the preceding paragraph. The tractor hours per acre denote the amount of time spent in the actual operation of the field machinery. The man-hour figure per acre will of necessity exceed the tractor hour figure because man-hours include, besides time spent in actual operation of the machine, maintenance work, seed preparation, repair work, etc. It will be noted (Table XII) that labor inputs per acre decrease as the farm size increases in all cases except that

TABLE XII

Labor and Tractor Hours per Acre by Specific Crops for the Seeding Season by Size of Farm

	SIZE ½ Section	¾ Section	1 Section
Wheat			
Average man-hours per acre	1.19	.99	.96
Average tractor hours per acre	.90	.76	.72
Average acres per farm	56.3	92.2	112.8
Barley			
Average man-hours per acre	1.44	1.09	1.14
Average tractor hours per acre	1.13	.84	.87
Average acres per farm	38.3	51.3	57.1
Oats			
Average man-hours per acre	1.37	1.26	1.10
Average tractor hours per acre	1.05	1.00	.84
Average acres per farm	37.4	49.4	54.3
Flax			
Average man-hours per acre	1.62	1.63	1.19
Average tractor hours per acre	1.34	1.31	.98
Average acres per farm	9.3	7.9	27.4

of barley. There are two possible explanations for this exception to increased labor efficiency as scale increases. One may be that the three-quarter section group have larger machines than the one section group, the larger machines being emphasized more in barley seeding operations. Still another explanation for the tendency of the three-quarter group size to have less hours per acre than the one section size during barley seeding operations may be explained in part by a more intensive working of the barley land by the one section group. This may have been occasioned by the poorer shape of the land on which the barley was sown in the one section group. On the other hand more of the barley in the three-quarter section group may have been sown on summerfallow land, thus necessitating less preparatory work for the seeding operation.

It was finally established that the three-quarter size group showed less labor inputs per acre because of the influence of both larger size of machinery and less intensive preparatory work for the barley seeding operations.[9]

2. Harvest season

The labor involved in the harvest season included all labor connected with swathing, combining, binder-cutting, stooking, threshing, stacking oat sheaves, hauling grain[10] and all other incidental labor such as machinery maintenance and granary repair.

It will be observed (Table XIII) that labor inputs per acre declined from the half-section group to the three-quarter section group

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9/Reference to Table X page 39, will show that the three-quarter group have on the average slightly larger cultivators and discs. Further reference to Table XI, page 46, (on frequency of operations) will point out that the one section group showed a greater intensity or frequency of operation for both cultivation and discing in barley seeding operations than in the case of the three-quarter group. Through the combined influence of both larger cultivators and discs and because of less intensive application of these two implements, it was concluded that this would explain the lower labor requirements per acre for barley in the three-quarter group.

10/No distinction was made between grain hauled direct to the town elevator and that which was hauled to granaries on the farm.

but increased again in moving from the three-quarter to the one section group. This occurred generally for all the crops except for flax. Again as in the case of seeding operations it is suspected that the three-quarter size group have the advantage in labor

TABLE XIII

Labor and Tractor Hours per Acre by Specific Crops for the Harvest Season by Size of Farm

	SIZE		
	½ Section	¾ Section	1 Section
Wheat			
Average man-hours per acre	1.64	1.35	1.43
Average tractor hours per acre	.89	.71	.77
Barley			
Average man-hours per acre	2.05	1.36	1.53
Average tractor hours per acre	.92	.75	.75
Oats			
Average man-hours per acre	2.34	1.88	2.09
Average tractor hours per acre	.92	.78	.73
Flax			
Average man-hours per acre	.95	.90	.90
Average tractor hours per acre	.60	.54	.44

efficiency because of the presence of larger size harvesting equipment. It was finally decided on the basis of the evidence submitted in the accompanying footnote that the predominant influence on labor inputs per acre has been the size of machine used, the three-quarter group having on the average the largest sized swathers and combines.[11]

11/Reference to Table X, page 39, will show that the three-quarter group have on the average slightly larger combines and swathers. The influence of larger size harvesting equipment in the three-quarter group

There appeared a tendency (Table XIII) for wheat and barley to require less labor per acre than for the case of oats in all size groups. It is suspected that this situation results from the greater use of the binder and threshing machine to harvest oats because oat straw is used for animal feed. This appeared to be supported on the basis of the data for the harvesting season.

3. The entire crop season

The labor involved in crop production for the entire crop season included all labor involved in the seeding and harvesting seasons and in addition labor involved in summerfallow work,[12/] picking and spraying weeds, spreading manure, stone picking and any other tasks not directly connected with the seeding and harvesting operations but which were in some way related to crop production during the year.

a. Wheat: The results (Table XIV) show that labor inputs and tractor hours were least on the three-quarter size farms with the highest amounts of labor inputs and tractor hours per acre in evidence on the half-section farms. The greater efficiency of labor use on the three-

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is shown again by results established in Table XVIII, page 61 where the farms were stratified on the basis of aggregate size of machinery. In this case (Table XVIII) labor inputs per acre during harvesting showed a general tendency to decline as size of machine increased. On the basis of this evidence it was decided that because the three-quarter section group had larger combines and swathers, it would explain their having less labor inputs per acre than the one section group.

12/For allocation of summerfallow work see page 8. It must be observed that only those crops grown on summerfallow land of the year preceding the year of this study were charged with the labor involved in summerfallow work.

quarter section size as compared to the one section size reflects again the influence of larger size of machinery.

b. Barley: The labor inputs and tractor hours per acre for barley production showed a decline as size of farm was increased. This

TABLE XIV

Labor and Tractor Hours per Acre by Specific Crops for the Entire Crop Season by Size of Farm

	SIZE ½ Section	¾ Section	1 Section	All Farms
Wheat				
Average man-hours per acre	5.77	5.11	5.42	5.37
Average tractor hours per acre	3.78	3.34	3.60	3.52
Barley				
Average man-hours per acre	5.31	4.19	4.10	4.49
Average tractor hours per acre	2.91	2.49	2.35	2.57
Oats				
Average man-hours per acre	5.27	4.26	5.17	4.79
Average tractor hours per acre	2.64	2.12	2.66	2.41
Flax				
Average man-hours per acre	3.35	3.00	2.97	3.07
Average tractor hours per acre	1.96	1.66	1.74	1.77

is not consistent with the tendency shown in the data for the seeding and harvesting seasons.

It can thus be concluded that the higher than expected labor requirements for barley production for the entire crop year in the three-quarter group is due to a greater proportion of the barley being sown on summerfallow.[13]

c. Flax: In the case of tractor hours per acre for flax production for the entire year, the three-quarter group showed up as most efficient. The man-hours per acre for flax production showed on the other hand, a tendency to decline as size of farm was increased.

d. Comparison of labor requirements for the different crops: It is to be noted (Table XIV) that wheat production involved significantly more total labor requirements for the year than in the case of any of the other crops. This is explained by the fact that a far greater proportion of the wheat was sown on summerfallow land than in the case of other crops.

While the total labor requirements for oats and barley seemed quite similar, the total labor requirements for flax was decidedly lower than for any other crops. It will be observed that the labor requirements for flax during the harvesting season were considerably below those of the other crops.[14] The explanation for this is that a large part of the flax was harvested by straight combining while the

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13/For both the seeding and harvesting seasons, the labor inputs per acre for barley production in the three-quarter size group were lower than for either of the other two size groups. This would have been reflected in the labor inputs for the entire crop year for the three-quarter group had not this tendency been offset by the fact that a relatively greater proportion of barley in the three-quarter group was sown on summerfallow.

14/Reference to Table XII, page 50, showing labor requirements for the different crops for the seeding season will indicate that flax actually involved a relatively greater amount of labor per acre. Thus it can be concluded that it was the technique of harvesting flax that made it possible to have less labor requirements than for any other crops for the entire crop period.

other crops were almost entirely swathed before being combined. Also the fact that flax seed is not as bulky as other grain seeds meant that there was less handling of the flax seed as compared to the other bulkier grains.

4. Summerfallow and weed spraying

The labor requirements for summerfallow work included direct operation of machines in the field and in addition any labor involved in maintenance and repair of the machinery while engaged in the summerfallowing operations.

The labor requirements for weed spraying of the crops included labor involved in actual operation of the spraying equipment and further any labor connected with maintenance and service of the machinery. Any labor involved in preparing the weed spray and filling the tank of the sprayer was also included under labor requirements for weed spraying.

It will be observed (Table XV) for the summerfallow operations that the labor requirements per acre were least on the three-quarter section size group, when farms were stratified according to size. The three-quarter section group had a greater efficiency in use of labor as compared to the one section group because the former group of farms had larger sized cultivators and discs; these two machines were used more than any other type of machine for summerfallow operations.[15]

15/See Table X, page 39 for average size of machinery on the different sizes of farms. It will be seen in this same table that the three-quarter size farms had on the average larger cultivators and discs than the one section group.

TABLE XV

Labor and Tractor Hours per Acre for Summerfallow and Weed Spray by Size of Farm

	Size of Farm		
	½ Section	¾ Section	1 Section
__Summerfallow__			
Average acres per farm	76.30	103.40	121.40
Average man-hours per acre	2.40	2.05	2.32
Average tractor hours per acre	2.16	1.84	2.10
__Weed Spraying__			
Average acres sprayed per farm	36.30	61.30	82.10
Average man-hours per acre	.10	.13	.19
Average tractor hours per acre	.08	.10	.14

It will be noted (Table XV) that the labor inputs per acre for spraying of weeds increased as size of farm increased. No evidence appeared available to explain this situation. It did not seem evident that the increase in labor inputs per acre as farm size increased could be explained by the size of weed sprayer used.[16]

5. __Machinery repair and miscellaneous tasks of crop production__

The labor used for machinery repair (Table XVI) included all labor spent on repair work during the entire crop season apart from that already accounted for in specific operations of machines either during the seeding or harvesting season. It included repair work on machinery during periods other than the seasons when machines were in-

16/Reference to Table X, page 39, will show that the half-section, three-quarter section and one section group of farms had an average size of weed sprayer of respectively 30.7, 28.6 and 30.7 feet.

volved in either seeding or harvesting operations.

Miscellaneous tasks of crop production included any tasks which could not be classified under any particular category but which were in some way related to the labor requirements of crop production. The miscellaneous tasks included such tasks as stone picking, spreading manure, hand picking of weeds, burning old straw piles, etc.

TABLE XVI

Man-Hours per Farm for Machinery Repair and Miscellaneous Tasks of Crop Production by Size of Farm

	$\frac{1}{2}$ Section	$\frac{3}{4}$ Section	1 Section
Machinery Repair			
Average man-hours per farm	101.0	137.3	155.0
Miscellaneous Tasks			
Average man-hours per farm	23.2	23.2	38.9

It will be seen (Table XVI) that average hours per farm of machinery repair increased as size of farm increased. This appears to be a logical tendency as more machinery and a greater possibility of breakdown would occur as farms increased in size. In the same table it will be observed that the average man-hours per farm of miscellaneous tasks were identical for both the half-section and three-quarter size groups but with a larger number of man-hours per farm on the one-section group.

C. The Effect of Mechanization on Labor Efficiency in Crop Production

The purpose of this section is to analyze the influence of mechanization on labor efficiency in crop production. This will mainly involve showing how an increase in size of machinery will cause a reduction in the labor inputs per acre. The size of machinery used here will be expressed as an index of aggregate machinery size.17/ Two main techniques will be used to analyze the effects of mechanization on labor requirements: the cross tabulation of farms according to aggregate size of machinery and the multiple regression analysis.

1. Cross tabulation analysis of labor requirements per acre by seasons, when farms are stratified on the basis of aggregate size of machinery

The specific objective of this section is to group farms according to aggregate size of machinery and then to determine the labor inputs per acre within each group. This cross tabular analysis of farms grouped according to aggregate machinery size and labor inputs per acre will be carried out for both the seeding and the harvest seasons. The purpose of the analysis will be to show the direct influence of machinery size on labor efficiency.18/

17/See Chapter IV, page 44 for the discussion on the calculation of this index of aggregate machinery size; also technical appendix p. 120.

18/See Tables XII, page 50 and XIII, page 52 where farms are stratified on the basis of assessed acreage to determine labor inputs per acre. It was expected that labor inputs per acre would decline as size of farm was increased. This did not appear to be the case. The three-quarter size group of farms showed a tendency for less labor requirements per acre than for the one section group. This resulted because the three-quarter group had larger machinery than the one section group. The grouping of farms according to assessed acreage tended to obscure the influence of machinery size on labor inputs per acre. Stratification of farms according to machinery size will reveal the influence of machinery size on labor inputs per acre.

a. The seeding season: It will be seen (Table XVII) that the labor requirements per acre declined for every crop except flax, as aggregate size of machinery was increased. The case of flax is not too representative as only a few farmers in the present study grew flax.

TABLE XVII

Man-Hours and Tractor Hours per Acre for the Seeding Season When Farms are Grouped According to Aggregate Machinery Size

	Aggregate Machinery Size		
	65-95	96-105	106-135
Wheat			
Average man-hours per acre	1.15	1.04	.92
Average tractor hours per acre	.86	.80	.70
Barley			
Average man-hours per acre	1.55	1.12	1.01
Average tractor hours per acre	1.20	.86	.76
Oats			
Average man-hours per acre	1.56	1.19	1.05
Average tractor hours per acre	1.20	.93	.85
Flax			
Average man-hours per acre	1.78	1.21	1.32
Average tractor hours per acre	1.43	1.01	1.06

By grouping the farms according to aggregate size of machinery it will be seen that size of machinery did exert considerable influence on the labor requirements per acre during the seeding season.

b. The harvest season: It will be noted (Table XVIII) that for every crop there was a consistent tendency for tractor hours per acre to decline as aggregate size of machinery was increased.[19] On

19/Compare these results with the results shown in Table XIII, page 52.

the other hand man-hours per acre for barley and oats appeared highest in the group having an index range of 86 to 115. The aggregate machinery size index did not reflect this situation because the index is calculated on the basis of tractor hours per acre.[20] The higher man

TABLE XVIII

Man-Hours and Tractor Hours per Acre for the Harvest Season when Farms are Grouped According to Aggregate Machinery Size[a]

	Aggregate Machinery Size		
	65-85	86-115	116-167
Wheat			
Average man-hours per acre	1.76	1.45	1.21
Average tractor hours per acre	.95	.74	.66
Barley			
Average man-hours per acre	1.75	2.11	1.11
Average tractor hours per acre	.90	.90	.62
Oats			
Average man-hours per acre	2.38	2.51	1.58
Average tractor hours per acre	.97	.83	.68
Flax			
Average man-hours per acre	1.29	.92	.65
Average tractor hours per acre	.70	.57	.34

(a) The group limits for aggregate machinery size for each of the three groups of farms of this table do not coincide with the group limits set out in Table XVII. This resulted from having to arbitrarily manipulate the group limits in order to secure enough farms within each group for purposes of comparison between the groups.

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where the largest size group of farms showed greater labor inputs per acre than the middle size group of farms. This was the result of the middle size group of farms, having larger machines on the average. When farms are grouped according to aggregate size of machinery (Table XVIII) there is a tendency for labor inputs per acre to decrease as aggregate machinery size is increased.

20/ See technical appendix for the calculation of the aggregate machine size index.

hours per acre for barley and oat harvesting in the middle size group is explained for the most part by the greater amount of harvesting done by the traditional method of binder, stooking and threshing machine. Closely associated with this method of harvesting is the need for more time on repair and maintenance of machinery, greater handling of grain as compared to the combine method which often dumps grain directly into granaries or waiting trucks. Frequently too, working efficiency per man in a threshing crew is lower as compared to the one or two man crew of the combine method of harvesting. Large crews of men demand greater organization of work if each man is to work at maximum efficiency. For example a breakdown of the threshing machine often detains not only the work of one man but often the whole crew.

It is to be observed (Table XVIII) that the tractor hours and man-hours per acre for wheat, barley and oats did not vary from one another very significantly. Flax however, showed considerably less tractor hours and man-hours per acre than for any of the other crops. The major influence here was the fact that flax was generally straight combined while the other crops required swathing before the combine harvesting operations.

D. Application of Multiple Regression Analysis in Determination of the Effect of Size of Machine and Size of Farm on Labor Efficiency

The objective of multiple regression analysis is to identify, isolate and measure the influence of each of two or more independent variable factors on a dependent variable factor. The multiple regression analysis was adopted in this study to act as supplementary analysis to the cross tabulation analysis of the influence of size of machinery and size of farm on labor efficiency in crop production. The multiple regression equation will give a plane of best fit to the prevailing labor inputs per acre as the size of machine and size of farm are varied. The multiple regression equation points out the trend in the data and will allow one to predict fairly reliably, depending of course on the degree of correlation between the variates, the labor input per acre given certain information on machinery size and size of farm.

While the present study makes use of cross tabulation analysis in determining the relationship between labor inputs per acre and the size of machine and size of farm, it was felt that this technique of analysis was not sufficient by itself. Cross tabulation analysis is simple and easy, as it is based upon arithmetic averages of the various sub-groups or stratifications but it offers no measurement as to how closely the factors being studied are correlated. Furthermore, the cross tabulation method of analysis cannot eliminate the causal relationship which might exist between size of farm and size of machinery used. For example in stratifying by size of farm to determine labor inputs per acre, there is no way of determining how much of the variation in labor inputs is due to size of machine.[21]

21/For a more technical discussion on this method of analysis see: Hopkin J.A., "Multivariate Analysis of Farm and Ranch Management Data", Journal of Farm Economics, Nov. Proceedings, 1949 pp. 1074.

In view of the limitations of cross tabulation in the analysis of the relationship between labor inputs and size of farm and size of machine it was decided to adopt the technique of multiple regression analysis. The purpose underlying the adoption of this technique was to be able to show more directly and more concisely the substitutionary relationship between labor and machinery in crop production. Multiple regression analysis will allow one to separate out the influence of size of machinery from the influence of size of farm on labor inputs in crop production. It will also measure the degree of correlation between the three factors studied as well as to establish the standard error of estimate which measures the reliability of the results obtained.

1. Application of multiple regression analysis to the data of the seeding season

In this study the dependent variate Y represented labor input per acre. Size of machinery and size of farm were represented by X_1 and X_2 respectively. Size of machinery on the individual farm is expressed as the aggregate machine size index as established in the foregoing section.[22] Size of farm is expressed in terms of total improved acres on the individual farm. Labor inputs per acre represented the labor directly engaged in operating the machinery.[23]

22/ See Chapter IV, page 44.

23/ This labor is equivalent to tractor hours per acre. It does not include any labor classified as hand labor. The hand labor was eliminated from the multiple regression analysis because it is not a direct function of size of machine.

TABLE XIX

Summary Data from the Multiple Regression Analysis for the Seeding Season

Multiple Regression Equation:

$Y = 2.3672 - .0153X_1 - .00002X_2$

$by_{1.2} = -.0153$	$ry_2 = -.2446$
$by_{2.1} = -.00002$	$Ry_{.12} = -.5242$
$r_{12} = +.4746$	$ry_{1.2} = -.4774$
$ry_1 = -.5236$	$ry_{2.1} = -.052$

T-Test for the Partial Correlation Coefficients:

(a) t value for $r_{y1.2} = \pm 4.18^{**(a)}$

(b) t value for $r_{y2.1} = \pm 0.404$

Standard Error of Estimate:

$s.y_{.12} = \pm .204$

95% Fiducial Limits:

$Y \pm 2_{sy.12}$

i.e. $Y \pm .408$

(a) $t_{(01)}$ (d.f. = 59) = 2.66

$t_{(05)}$ (d.f. = 59) = 2.00

This means that the T-test shows $ry_{1.2}$ as being highly significant beyond the one per cent level.

Note: Y - tractor hour inputs per acre
X_1 - aggregate machinery size index
X_2 - size of farm expressed as improved acres

a. Interpretation of the results

(i) The multiple correlation coefficients: The simple correlation coefficient r_{12} indicates a positive correlation of + .4746 between size of machinery and size of farm. While the r_{12} coefficient indicates a relationship between machine size and size of farm, the magnitude of the coefficient implies that a considerable amount of the variation in machinery size is not explained by variation in size of farm (an r_{12} coefficient of + 1 would indicate perfect correlation). This conclusion seems supported by the cross tabular analysis carried out in a preceding section on machinery distribution by size of farm. The cross tabular analysis by size of farm and size of machinery suggested considerable variation in size of machinery in any given farm size group. Some machines appeared to increase in size as farm size was increased while other machines showed a negative tendency to decrease in size as farm size increased.[24]

The simple correlation coefficient r_{y1} showed a negative correlation of -.5236 between aggregate size of machinery and labor inputs per acre. It suggests that as size of machine increased there was a tendency for labor inputs per acre to decrease. This tendency points out quite well the substitutionary relationship between labor and machinery in crop production. It will be noted in the cross tabulation analysis of labor inputs per acre when farms are stratified according to aggregate size of machinery that labor inputs decline as aggregate

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24/ See Table X, page 39 for the cross tabular analysis of farm size and size of machinery.

size of machinery increases.[25] The simple correlation coefficient r_{y1} adds to the validity of the cross tabular analysis. i.e. the negative correlation between machinery size and labor requirements.

The degree of correlation between size of farm and labor inputs per acre was indicated by r_{y2} with a value of -.2446. This shows that as size of farm is increased labor inputs per acre tend to decrease. The correlation between farm size and labor inputs per acre is lower than the correlation between size of machinery and labor inputs per acre.

The overall multiple correlation coefficient $R_{y.12}$ with a value of -.5242 indicates the combined effects of machinery size and farm size on labor inputs per acre. As farm and machinery size are increased labor inputs per acre will tend to decrease. Because $R_{y.12}$ is only slightly larger than r_{y1} - almost as good a job of estimating can be done with machine size alone as the independent variate. Size of improved acreage as a measurement of farm size seems to contribute little information.[26]

(ii) Partial correlation analysis: The partial correlation coefficient $r_{y1.2}$ is an estimate of the correlation between Y and X_1 in a population whose members all have the same X_2. The partial correlation coefficient with a value of -.4774 is shown to be highly

[25] See Table XVII, page 60 for the cross tabulation analysis of labor inputs per acre as aggregate size of machinery is increased.

[26] For implications of this conclusion see: Snedecor Geo.W. Statistical Methods, The Iowa State College Press, Ames, Iowa, 1950. pp. 348.

significant when the T-test is applied. This suggests that there is a significant negative correlation between labor inputs per acre and size of machinery when the size of farms remains constant. On the other hand, the partial correlation coefficient $r_{y2.1}$ with a value of -.052 estimates the negative correlation between labor inputs per acre and size of farm when machinery size is held constant. When the T-test was applied to $ry_{2.1}$ it showed no significant relationship between farm size and labor inputs per acre.

(iii) Standard error of estimate: The multiple regression equation is used to estimate a theoretical value of Y for given values of X_1 and X_2. In other words with this equation a theoretical value for labor inputs per acre can be established with given values for size of machinery used and size of farm. If the relationship (i.e. the multiple correlation coefficient) is not perfect the actual values of labor inputs will not coincide with the theoretical or estimated values, because of the scatter or variation about the regression plane. If the scatter is definitely measured the variation may then be allowed for and a range established within which a definite percentage of the values will fall. The measure used for this purpose is the standard error of estimate. It is a measure of the variation or scatter about the regression plane. The value established in this case for the standard error of estimate was $s_{y.12} = .204$. From this result one can establish the fiducial limits, i.e. the range within which 95 per cent of the estimates will fall and the probability of the occurrence. In the present case the 95 per cent fiducial limits were $Y \pm .408$.

This means that for any estimated value of Y, there is the probability that ninety-five times out of a hundred the true value of Y will fall within the range Y $\pm$ .408.

b. Fitting the multiple regression equation to the data: The multiple regression equation derived above will be applied to the data of the present study. The multiple regression equation takes account of the effect of both size of machinery and size of farm on labor inputs per acre.[27] However, only the relationship between aggregate size of machinery and labor inputs per acre will be shown here. This will be accomplished by holding the variable for size of farm at a constant value.

It will be observed (figure 1) that the tractor hours per acre are plotted along the Y-axis of the diagram and aggregate machinery size along the X-axis. Each point of the scatter diagram indicates the average tractor hours per acre and the aggregate machinery size of an individual farm. The straight line shown in figure 1 was derived from the corresponding multiple regression equation for data of the seeding season.

While the scatter diagram indicates considerable variation about the regression line there appears to be a general tendency for tractor hours per acre to decline as aggregate machinery size is increased. No deliberate attempt was made in the present study to gather data

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27/It must be emphasized here again that labor inputs as used in the multiple regression analysis stands for the amount of labor associated with the actual operation of the field machinery. This is synonomous with tractor hours. It means that the multiple regression equation takes no direct account of the labor described as hand labor in the present study.

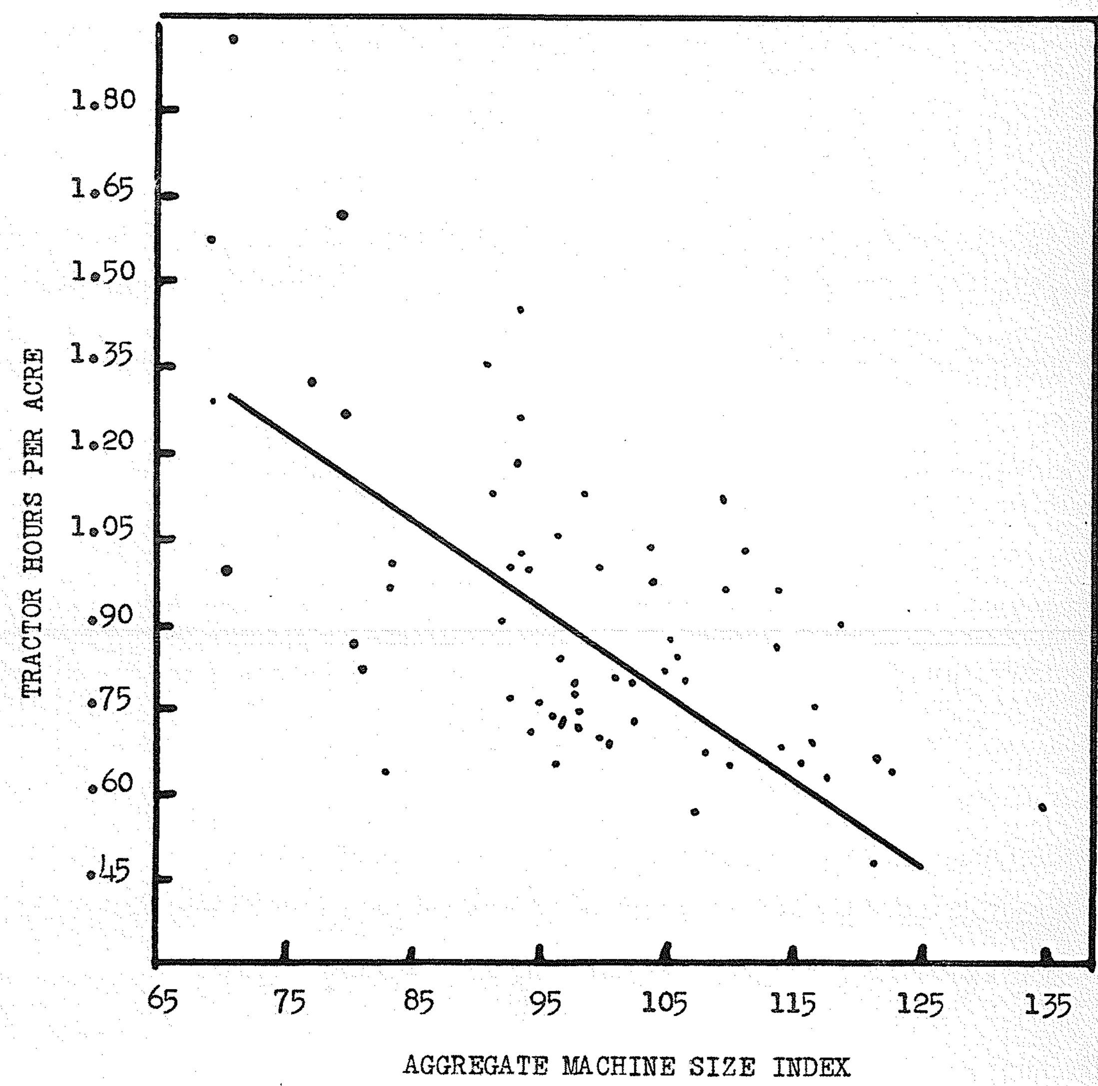

Figure 1

Scatter Diagram and Regression Line of Tractor Hours per Acre and Aggregate Size of Machinery for the Seeding Season which might have explained this variation about the regression line but it is suggested that factors other than machine size had a considerable influence on the magnitude of the tractor hours per acre in crop production.

2. Application of multiple regression analysis to the data of the harvesting season

As in the case of the seeding season, the dependent variate Y will represent the labor inputs per acre. Aggregate size of machinery and size of farm will be represented by X_1 and X_2 respectively. Size of machinery is measured in terms of the aggregate machine size index and size of farm is expressed as total improved acres on the individual farm. Labor inputs per acre represents the labor directly engaged in operating the machinery in the field.

TABLE XX

Summary Data from the Multiple Regression Analysis for the Harvest Season

Multiple Regression Equation:

$Y = 1.6423 - .0048X_1 - .0012X_2$

$by_{1.2} = -.0048$	$ry_2 = -.6200$
$by_{2.1} = -.0012$	$Ry_{.12} = -.7710$
$r_{12} = + .3610$	$ry_{1.2} = -.58$
$ry_1 = -.6510$	$ry_{2.1} = -.54$

T-Test for the Partial Correlation Coefficients:

(a) t value for $r_{y1.2} = \pm\ 5.52^{**(a)}$

(b) t value for $r_{y2.1} = \pm\ 5.02^{**}$

Standard Error of Estimate:

$sy_{.12} = .147$

95 % Fiducial Limits

$Y = 2\ sy_{.12}$

i.e. $Y \pm .294$

(a) $t_{(01)}$ (d.f. 59) = 2.66

$t_{(05)}$ (d.f. 59) = 2.00

This means that the T-test show both $ry_{1.2}$ and $ry_{2.1}$ as both being highly significant beyond the one per cent level.

Note: Y - tractor hour inputs per acre
X_1 - aggregate machinery size index
X_2 - size of farm expressed as improved acres

a. Interpretation of the Results

(i) Multiple correlation coefficients: The simple correlation coefficient r_{12} with a value + .361 indicates the relationship between size of machinery used and size of farm. The simple correlation coefficient appears to reinforce the results established by the cross tabulation analysis of average size of harvesting machinery by size of farm.[28/]

The relationship between size of machinery used for harvesting and labor inputs per acre was shown by the correlation coefficient ry_1 with a value -.651. This suggests that as size of machinery was increased there was a tendency for labor inputs per acre to decline. This again points out the substitutionary relationship between labor and machinery in crop production. The cross tabulation analysis of labor inputs per acre when farms are stratified according to aggregate size of machinery appears to be supported by the results of the multiple regression analysis shown here on relationship between size of machinery and labor inputs per acre.[29/]

The simple correlation ry_2 (-.620) shows the relationship between the size of farm and labor inputs per acre. Labor inputs per acre

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28/See Table X, page 39 on the cross tabular analysis of machinery size and size of farm. It will be noted from this table that the average size of combine and swather on the three-quarter size farms exceeded that on the one section size farms.

29/See Table XVIII, page 61 for the results of the cross tabulation analysis of labor inputs per acre and size of machinery.

declined as the size of farm increased. The value of -.620 for ry_2 indicates a relatively greater correlation between size of farm and labor inputs per acre for the harvest data as compared to the seeding data. To explain this relatively higher correlation it was necessary to seek out those factors associated with size of farms that would appear to effect greater labor efficiency as size of farm increased. It was suspected that the proportion of self-propelled combines as compared to tractor drawn combines increased as size of farms increased. Table XXI will show this to be actually the case.

TABLE XXI

Distribution of Types of Combines by Size of Farm

	½ Section		¾ Section		1 Section	
	No.	%	No.	%	No.	%
Pull type 10' - 12'	2	33	3	27	2	25
Self-propelled type 10' - 12'	4	67	8	73	6	75

The tendency for the self-propelled combine to be associated with increasing size of farm will help to explain the high regression relationship between size of farm and labor inputs per acre during the harvest season. The self-propelled combine is more adaptable to small fields or fields of irregular patterns. Its greater manoeuverability as compared to the tractor drawn type, permits it to cover an acre in relatively less time. The aggregate machinery size index does not reflect the greater effectiveness of a self-propelled combine as compared to a pull-type combine when both are of the same width. Hence one of the reasons for the multiple regression analysis to reveal a high relationship between size of farm and labor efficiency.

There are good indications that there exists an association between size of farm and size of field. That is, larger fields are associated with larger farms. It has been established in other studies that a machine operates more effectively on large fields as compared to smaller fields. Assuming this condition, it is logical to suspect then that the high relationship between size of farms and labor inputs per acre may be due in part to the association of larger fields with larger farms. However, this is only a conjecture as no data was gathered on field size in the present study.

The overall multiple correlation coefficient $Ry_{.12}$ (-.771) indicates the combined effects of machinery size and farm size on labor inputs per acre. The multiple correlation coefficient $ry_{.12}$ is considerably higher than either of the other two simple correlation coefficients ry_1 and ry_2 so neither one of the latter two coefficients will estimate by themselves, the amount of labor requirements per acre. Estimation of labor inputs must be based on the combined effects of both machine size and farm size.

(ii) <u>Partial correlation analysis</u>: The partial correlation coefficient $ry_{1.2}$ with a value of -.58 shows the negative correlation between aggregate size of machinery and labor inputs per acre when size of farm is held constant. It can further be concluded from this result that the constant size of farm did not exert any extreme influence on the operating effectiveness of a machine which varied in size. This appears to be corroborated by the magnitude of the simple correlation coefficient r_{12} (+ .361) between size of farm and size of machinery. In other words there appears to exist a fair degree of flexibility between size of farm and size of machinery; varying sizes of machinery can be applied to a constant size of farm with only a moderately expected change in the technical input-output ratio between increases in machine width and amount of acres that can be handled per hour. The partial correlation coefficient $ry_{2.1}$ with the value of -.54 shows the magnitude of the negative correlation between size of farm and labor inputs per acre when machinery size is held constant. The T-test for the partial correlation coefficients indicates that both coefficients are highly significant. It can be concluded from this that both $ry_{1.2}$ and $ry_{2.1}$ show respectively a highly significant correlation between size of machinery and labor inputs per acre and size of farm and labor inputs per acre.

(iii) Standard error of estimate: The standard error of estimate for reliability of the predictive value of the multiple regression equation was $sy_{.12} = + .147$. The 95 per cent fiducial limits were determined as $Y \pm .294$. This means that for any estimated value of Y (i.e. labor inputs per acre) there is the probability that 95 per cent of the time the true value of Y will fall within the range $Y \pm .294$.

b. Fitting the multiple regression equation to the data: The multiple regression equation corresponding to the data of the harvest season is shown in the form of a straight line in figure 2.

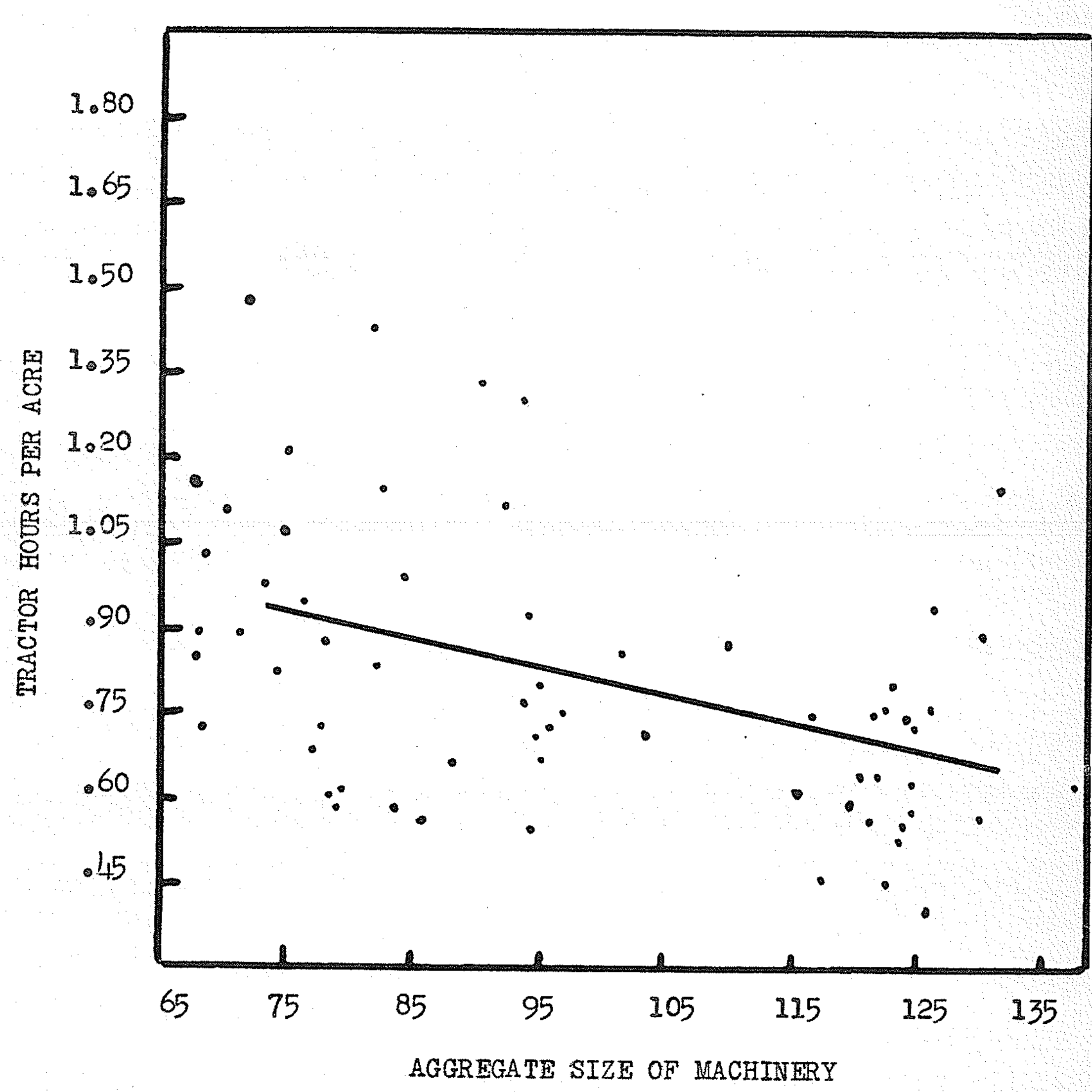

Figure 2

Scatter Diagram and Regression Line of Tractor Hours per Acre and Aggregate Size of Machinery for the Harvest Season

As in the case of fitting the multiple regression equation to the data of the seeding season, only the relationship between aggregate machinery size and tractor hours per acre will be shown in the figure. Each point of the scatter diagram corresponds to the average tractor hours per acre and aggregate machinery size of an individual farm.

The scatter diagram indicates considerable variation about the regression line but as in the previous case there appears to be a general tendency for tractor hours per acre to decline as aggregate machinery size is increased. The variation of the points around the regression line indicates that other factors than size of machinery have considerable influence on tractor hours per acre. However, the present study has not sufficient data to offer an explanation for this variation.

E. Variations in Machinery Size and Labor Requirements Within a Given Size of Farm

It will be the objective here of setting out the variations that occur within a given size group of farms. It will be shown that labor requirements and machinery size not only vary for different sizes of farms but vary significantly within any given size. The implications of this situation point out the need for research not only on labor efficiency as it varies between different sizes of farms but for intra-farm-size variations. A further implication of this intra-farm-size variation in labor efficiency is that much could be accomplished in improving labor efficiency without changing the size of farm unit.

The analysis will set out the variations that occur during the seeding and harvesting seasons for each of the half-section farms and for the three-quarter section farms. No such analysis was attempted for the one section group as it was felt that the number of farms within the group were not sufficient to allow any warrantable conclusions to be drawn. However, the conclusions arrived at for the one-half and three-quarter section sizes should apply in general to the one section group.

The farms within the one-half section group were stratified into three sub-groups according to aggregate size of machinery.[30] Within each sub-group calculations were made to determine the average labor requirements per acre. In this way variations in machinery size and labor requirements could be shown for the one-half section group. In a similar way calculations were made to show the variations that occur in labor requirements and machinery size for the three-quarter section size group of farms.

1. Variations on the half-section farms

The variations in labor requirements per acre and aggregate size of machinery for the half-section farms were calculated separately for the seeding season and for the harvesting season.

a. Seeding season: The farms in the half-section group were stratified on the basis of aggregate size of machinery into the three respective sub-groups: 71 to 90, 91 to 96 and 97 to 122. Calculations were then made within these three sub-groups for the average man-hours

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[30] The range of the aggregate machinery size for each sub-group was arbitrarily determined. This was necessary because the entire range of the aggregate machinery sizes for both the one-half and

and tractor hours per acre required for the seeding operations for wheat, barley and oats.

It will be noted (Table XXII) that the middle size group had the

TABLE XXII

Man-Hours and Tractor Hours per Acre for the Seeding Season when Farms Within the One-Half Section Size are Grouped According to Aggregate Size of Machinery

	Aggregate Machinery Size		
	71-90 7 Farms	91-96 9 Farms	97-122 8 Farms
Wheat			
Average man-hours per acre	1.10	1.16	.97
Average tractor hours per acre	.81	.90	.73
Average acres per farm	50.70	50.20	56.40
Barley			
Average man-hours per acre	2.02	1.40	1.09
Average tractor hours per acre	1.64	1.10	.81
Average acres per farm	29.00	41.00	39.50
Oats			
Average man-hours per acre	1.72	1.34	1.07
Average tractor hours per acre	1.38	1.05	.77
Average acres per farm	37.40	41.00	39.20

highest man-hour and tractor hour requirements for wheat seeding operations. It suggests that some influence other than size of machinery has caused the highest man and tractor hours in this group. For both

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the three-quarter section farms were significantly different. This will explain why the aggregate machinery size range for the sub-groups of the half-section farms do not coincide with that of the three-quarter section farms.

barley and oats the man and tractor hour requirements per acre declined as aggregate size of machinery was increased. The most striking thing about the results shown in this table is the range of variations that occurs for both machinery size and the labor requirements within the half-section group of farms. In barley seeding operations for example, the labor requirements per acre vary from 2.02 hours to 1.09 hours per acre. In oat production the range of variation in labor requirements is from 1.72 hours to 1.07 hours per acre.

b. Harvest season: The farms were stratified on the basis of aggregate machinery size into three sub-groups: 68 to 80, 81 to 100 and 101 to 130. Within each sub-group calculations were made for the man and tractor hour requirements per acre.

It appeared that tractor hours per acre (Table XXIII) seemed to decline as aggregate machinery size increased with the exception of the middle size group (81 to 100) in barley harvesting. There appeared to be a tendency for the middle size group to have more man-hours per acre than either of the other two groups. No explanation could be found for this situation. It does seem that some other factor than size of machinery had an influence on the variation in labor inputs per acre.

The results shown in this table indicate considerable variation in labor requirements per acre for harvesting in the half-section group. The range in wheat was from 1.37 man-hours per acre to 2.02 man-hours; for barley the range was from 1.94 to 2.11 man-hours per acre; and for oats from 1.84 to 3.13 man-hours per acre. It is suggested that factors other than machinery size helped cause the range in labor inputs per acre.

TABLE XXIII

Man-Hours and Tractor Hours per Acre for the Harvest Season when Farms Within the One-Half Section Size are Grouped According to Aggregate Size of Machinery

	Aggregate Machinery Size		
	68-80 10 Farms	81-100 7 Farms	101-130 7 Farms
Wheat			
Average man-hours per acre	1.60	2.02	1.37
Average tractor hours per acre	.96	.96	.75
Average acres per farm	48.10	52.60	58.30
Barley			
Average man-hours per acre	2.11	2.07	1.94
Average tractor hours per acre	.96	1.00	.75
Average acres per farm	29.60	46.40	37.70
Oats			
Average man-hours per acre	2.25	3.13	1.84
Average tractor hours per acre	1.11	.92	.69
Average acres per farm	36.50	35.30	46.70

2. Variations on the three-quarter section farms

As in the case of the half-section farms, the variations in labor requirements and aggregate size of machinery for the three-quarter size farms were calculated separately for the seeding season and for the harvesting season.

a. Seeding season:

The farms in the three-quarter section group were stratified on the basis of aggregate size of machinery into the three sub-groups: 69 to 95, 96 to 110 and 111 to 134. Average man and tractor hours per acre were then calculated within these three sub-groups.

In every case (Table XXIV) it will be seen that labor requirements and tractor hours per acre declined as aggregate size of machinery was increased. The results established here, point out the

TABLE XXIV

Man-Hours and Tractor Hours per Acre for the Seeding Season when Farms Within the Three-Quarter Section Size are Grouped According to Aggregate Size of Machinery

	Aggregate Machinery Size		
	69-95 6 Farms	96-110 12 Farms	111-134 6 Farms
Wheat			
Average man-hours per acre	1.13	1.02	.84
Average tractor hours per acre	.83	.81	.62
Average acres per farm	69.70	98.90	120.70
Barley			
Average man-hours per acre	1.50	.96	.96
Average tractor hours per acre	1.13	.75	.67
Average acres per farm	47.80	52.90	46.90
Oats			
Average man-hours per acre	1.54	1.30	.90
Average tractor hours per acre	1.15	1.06	.73
Average acres per farm	59.80	51.90	51.30

significant variation that occurs in the labor and tractor hours per acre for seeding operations within the three-quarter size group.

When comparisons are made between Table XXII for the half-section group and Table XXIV for the three-quarter size group it appears that by far the greater variation in labor requirements per acre seemed to occur within the half-section group of farms.

b. Harvest season:

The farms were divided into three groups with the following ranges for aggregate size of machinery: 71 to 90, 91 to 110 and 111 to 140. Variations in labor requirements during the harvest season for the three-quarter size group of farms were shown by comparing the results of the three sub-groups.

There appeared to be a tendency for the middle size group to have the largest man and tractor hours per acre (Table XXV). None

TABLE XXV

Man-Hours and Tractor Hours per Acre for the Harvest Season when Farms within the Three-Quarter Section Size are Grouped According to Aggregate Size of Machinery

	Aggregate Machinery Size		
	71-90 6 Farms	91-110 7 Farms	111-140 12 Farms
Wheat			
Average man-hours per acre	1.30	1.66	1.22
Average tractor hours per acre	.77	.79	.63
Average acres per farm	111.30	82.30	95.70
Barley			
Average man-hours per acre	1.14	1.92	1.13
Average tractor hours per acre	.72	.96	.64
Average acres per farm	35.30	53.00	55.30
Oats			
Average man-hours per acre	2.44	1.96	1.57
Average tractor hours per acre	.81	.90	.70
Average acres per farm	49.70	55.70	54.60

of the available data seemed to suggest any explanation for this situation. However, it can be concluded that other factors had more of an influence than size of machinery in causing variations in the labor requirements per acre in the three-quarter size group of farms.

There appears to be a considerable range of variation in man and tractor hour requirements per acre. In wheat harvesting operations the range of variation in labor inputs per acre varied from 1.22 to 1.66 hours per acre; in barley harvesting from 1.13 to 1.92 hours per acre; and in oat harvesting from 1.57 to 2.44 hours per acre.

3. Summary

It has been shown that there is a significant range of variations in labor inputs per acre within any given size of farms. The variation has occurred for both the seeding and the harvesting seasons. Both the half-section farms and the three-quarter section group evidenced considerable variation in machinery size as measured by the aggregate machinery size index and in labor requirements per acre.

It will be noted that while a significant relationship has been established between labor inputs per acre and aggregate size of machinery, considerable unpredictable variation occurs as aggregate machine size is varied. Thus it can be concluded that while machinery size is the predominant influence on labor efficiency, other unexplained factors had some effect on the variation in labor inputs per acre for any given size of farms.

F. Significance of Hand Labor in Crop Production

It is quite often believed that labor efficiency in crop production is a direct function of machine efficiency and hence, the only avenue open to reducing labor input is by increasing the operating capacity or the efficiency of the machine. It is difficult to believe that hand labor should be of any significance in production of wheat, a crop generally adapted to areas ideally suited to large scale mechanization.[31] According to estimates made in United States for the nation as a whole, 24 per cent of the total hours expended in wheat production were directly attributable to hand labor.[32] With increased mechanization and through elimination of hand tasks which lend themselves to mechanical operations, it is estimated that a reduction of 35 per cent in hand labor of wheat production should be possible between 1944 and 1954.

Hand labor as defined in this study includes all labor involved in crop production apart from the actual operation of the field machine. This includes labor involved in repairing and servicing machinery, stone picking, cleaning seed, stooking, forking sheaves when the threshing machine is used, grain handling,[33] stacking sheaves, repairing granaries

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31/Hand labor is defined in this study as any labor involved in crop production apart from the actual operation of the field machine.

32/This estimate for the United States is taken from: Cooper, M.R., Barton, G.T., and Brodell, A.P., Progress of Farm Mechanization, Miscell. Public. No. 630, U.S.D.A., Oct. 1947. pp. 28-30.

33/Grain handling included the handling of grain at the combine or thresher and again at the initial place of storage. No distinction was made between grain hauled to a granary on the farm and that hauled directly to the town elevator.

and any other unique tasks connected to crop production but which involved hand labor.

During the seeding season, hand labor constituted anywhere from 17 to 27 per cent of the total labor expended on production of wheat, barley, oats and flax (see Table XXVI). There appeared to be no sig-

TABLE XXVI

Amount of Hand Labor Used in Crop Production and Percentage This is of Total Labor Used, by Seasons[a]

Crop and Season	½ Section Hand Lab. Hrs/acre	½ Section % Hand Lab.	¾ Section Hand Lab. Hrs/acre	¾ Section % Hand Lab.	1 Section Hand Lab. Hrs/acre	1 Section % Hand Lab.
Seeding Season						
Wheat	.29	24	.23	23	.24	25
Barley	.31	27	.25	23	.27	24
Oats	.32	23	.26	21	.26	24
Flax	.28	17	.32	20	.21	18
Harvest Season						
Wheat	.75	46	.64	47	.66	46
Barley	1.13	55	.61	45	.78	51
Oats	1.42	61	1.10	58	1.36	66
Flax	.35	37	.36	40	.46	51
Entire Crop Season						
Wheat	1.99	34	1.77	35	1.82	34
Barley	2.40	45	1.70	41	1.75	43
Oats	2.63	50	2.14	50	2.51	49
Flax	1.39	41	1.34	45	1.23	41

(a)Hand labor is expressed as a percentage of the total labor inputs per acre.

nificant variation in the percentage of hand labor either between the various crops or between the different sizes of farms. Flax if anything, involved the least hand labor.

Hand labor involved a spectacularly large percentage of the total labor during the harvesting operations. The proportion of hand labor in wheat production amounted to just a little under half of the total labor. Hand labor in barley harvesting operations ranged from 45 per cent to 55 per cent of the total labor. Oats involved a significant proportion of hand labor ranging from 58 to 66 per cent of the total labor. Flax showed somewhat less hand labor, although it amounted to just a little over half on the one section farms. There appeared to be no marked relationship between size of farm and the proportion of hand labor involved in harvesting the different crops. If there was any tendency at all for the proportion of hand labor to be related to size, it might be suggested in the harvesting of flax where the percentage of hand labor appeared to increase as size of farm increased.

The percentage of hand labor in crop production for the entire year occupied a position somewhat midway between that of the seeding and harvesting operations. Hand labor in wheat production for the entire year remained fairly constant around 34 to 35 per cent. Barley production for the entire year involved anywhere from 41 to 45 per cent hand labor. Flax production involved a proportion of hand labor quite similar to that of barley. Oat production showed a significant variation in the proportion of hand labor for the entire year, ranging from 27 per cent on the three-quarter size to around 50 per cent on the two other size groups. The relatively low percentage of hand labor in oat production on the three-quarter size farms may be explained in large part by the greater use of combines.

1. Significance of the results

One of the most important conclusions to be drawn from the results of the analysis on hand labor in crop production is that crop production is by no means fully mechanized. While a part of the hand labor could be eliminated by greater development of mechanization in crop production many tasks remain which do not lend themselves well to mechanical processes.

Further mechanization could occur especially in the harvest season. Much harvesting is still performed by the old method of binder, stooking and threshing machine. Combines in replacing the traditional methods of harvesting, could effect a considerable reduction in the labor requirements per acre. Stacking of sheaves could be mechanized somewhat more but this would show little reduction in hand labor requirements. There are some tasks that could be mechanized but which would not be economical to the individual farm operator. For example, many farmers hand pick mustard. The mustard is not thick enough to warrant the purchase of a mechanical sprayer and yet it is picked because it would spread if left. Other similar tasks such as spreading manure and picking stones could be more fully mechanized but the purchase of specialized machines for such tasks is not entirely justified in a majority of cases.

While many tasks involved in crop production are not adaptable to mechanization, these same tasks could involve less hand labor by proper organization and by suitable work-simplification techniques. For example, in refueling tractors, considerably less hand labor would be involved if farmers installed overhead fuel tanks. Likewise in handling grain, one could anticipate a considerable reduction in hand labor if more portable grain loaders were used. Various other incidental tasks such as repairing granaries and machines, while difficult to mechanize, would require less hand labor by the adoption of better work-simplification techniques.[34]

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[34] For a similar discussion see: Starch E.A., Farm Organization as Affected by Mechanization, Dept. of Agricultural Economics, Montana State College, Bull. No. 278, 1933. p. 45.

CHAPTER V

APPLICATION OF THE RESULTS IN FARM MANAGEMENT RESEARCH

A. Cost of Production Studies in Grain Growing

It will be the purpose here to show how input-output data such as that gathered in the present study provides basic information for studies on costs of production in grain growing. Physical input-output data are one of the primary needs in any research on efficient resource allocation in crop production.

Considerable farm management research has been devoted to studies on the costs of production of different grains. While valuable contributions have been made to knowledge on production costs, some limitations in the techniques employed to determine the costs may be pointed out. In most studies the particular costs of the individual production factors have not been segregated out. The costs of grain production are usually expressed as an aggregate figure. This is the result of estimating costs of producing any given crop on the basis of the expense which remains as a residual after subtracting all other expenses not connected with the crop under study. The residual expense is attributed to the cost of producing the crop and while it indicates the aggregate cost it does not however, allow one to estimate the relative importance of the costs of the individual input factors.1/

1/In correspondence with Dr. C.C. Spence of the Dominion Economics Division, University of Alberta, February 12, 1952 he states: "The method employed was to sort out the records of farms fairly pure for the wheat type; and by assuming the costs of the minor enterprise to balance out the revenue received therefrom, we

If costs are allocated to the specific input factors, it is done in most cases on some arbitrary basis. Such results are extremely limited and often misleading. This implies the need for data on the relative amounts of labor, machinery and land involved in crop production. Because machinery in replacing labor in crop production, tends to be of a cost minimizing nature, it is necessary to have information on the substitutionary relationship which exists between labor and machinery in crop production. Once having attained information on such basic physical input-output data the solution to efficient resource allocation can be achieved by applying appropriate cost data.

This cost curve approach to analysis of cost of production in grain growing is well adapted to studies on efficient resource use. It allows the determination of efficient resource use both within a given size of farm and also on farms of variable sizes. Changes in the technology or variations in the factor-price relationships of grain production can be readily evaluated through the use of the cost-curve analysis. This cost-curve technique also allows the segregation of costs associated with changes in size of the farm from those costs associated with various combinations of labor and machinery on a given size of farm.

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deducted that revenue from the total farm expenses and considered the remainder of the expenses to be attributable to the wheat enterprise ....However, this method of approach is not the one which we should have used had we had the specific inputs of labor, machinery, etc. to relate to wheat production."

Reference to figure 3 will illustrate how studies on efficient resource allocation in crop production depends on the cost-curve analysis. The cost curves designated as AC_1, AC_2 and AC_3 in figure 3 represent respectively cost curves for three increasing sizes of farms. The three respective short-run cost curves designate different sizes of farms each with a part of their resources fixed or invariable as output is varied. The long-run cost-curve on the other hand, represents minimum costs of production at varying scales of size when none of the resources are fixed in nature as output is increased. If a given farm size represented by cost-curve AC_1 is taken to represent a farm on which the proportions of labor and machinery are changed in relation to a fixed quantity of land, it may be shown how costs of production in grain growing will vary as output is increased. At first production costs would decline to the point where minimum costs of production would be attained for that size of farm; output beyond that point would cause production costs to rise.[2] Under the assumptions of perfect competition the point of optimum resource allocation with the given factor-price relationships would

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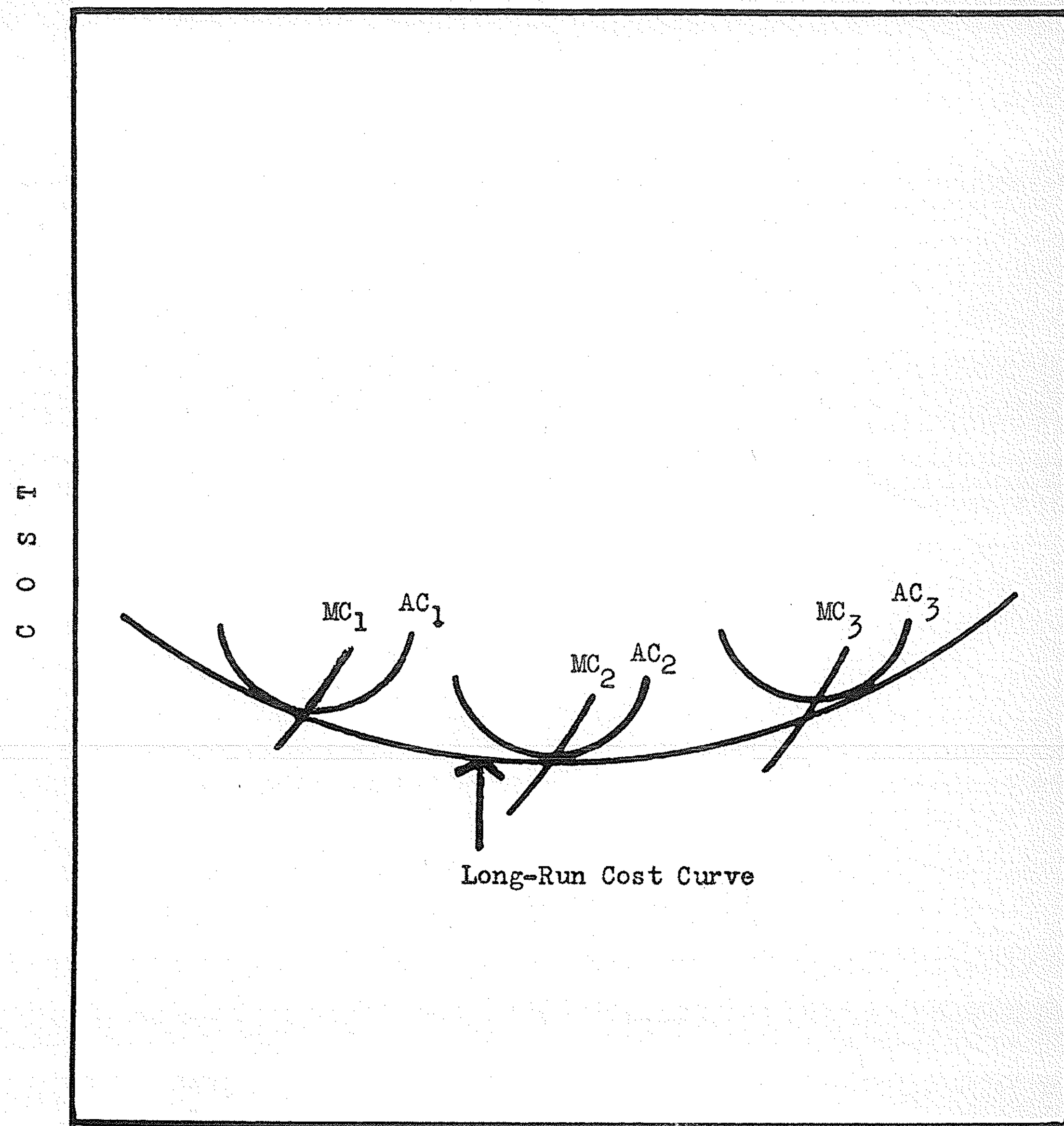
2/For a technical explanation of why average total costs at first decline and then eventually began to rise see: Fellows, I.F., "The Application of Static Economic Theory to Farm Management Problems," Journal of Farm Economics, Nov. Proceedings, 1950. pp. 1101-1103. He states: "When all inputs are considered under two headings of fixed and variable costs in the short run, average total costs will decline rapidly at first as output increases because fixed costs are being spread over more units; then, after reaching a low point, average unit cost will increase as a result of diminishing physical returns."



OUTPUT

Figure 3

Hypothetical Demonstration of the Long-Run Cost Curve and Short-Run Cost Curves for Individual Firms be the point where minimum costs of production are attained on the cost curve AC_1. This is the point towards which input-output research of crop production should guide the farmer in his allocation of resources. The physical input-output data such as that gathered in the present study together with additional information on costs of the labor, machinery and land will enable cost of production studies to determine that position on the cost curve where each farmer would be with his given organization of land, labor and machinery.

The cost-curve analysis of grain production has utility at many levels. The individual farmer has a vital interest in such a study. It would help him in seeking an optimum combination of resources in grain production on his farm. It will allow him to see how changes in the amounts of machinery or labor used will affect the income position of his farm. The effect of changes in size of farm on costs of production will also be made evident to him.

Farm management research is also in need of such an analysis. Studies on the effects of technological changes on costs of grain production, evaluation of the importance and significance of the individual factors of production in grain growing are some of the needs of farm management research.

The need for information on costs of grain growing is also in evidence at the national and international levels of agricultural policy. Production subsidies to be compatible with efficient resource allocation must be based on the farmers' costs of growing grain. The

International Wheat Agreement which sets a given price for wheat to farmers, recognizes the importance of data on the costs of production of wheat growing. One writer who had made a thorough and comprehensive study on the possibility of an International Wheat Agreement as far back as the early 1930's, recognized the urgent need and the difficulty of securing information on the production costs of wheat.3/

B. Construction of an Optimum Size of Farm with Given Amounts of Labor and Machinery

The capacity for getting work done within the number of days prescribed by nature provides an upper limit to the acreage a farmer can properly take care of with a given labor force.

With the given data on labor inputs per acre, the amount of labor available and length of time available within which the work must be performed, one can calculate the maximum number of acres that can be handled. This section will show that with the given data of this study, the size of farm is determined primarily by that season which is least efficient in the use of labor - in this case the harvesting season.

The labor inputs per acre required for seeding and for harvest

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3/De Hevesy, Paul, Le Probleme Mondial Du Ble, Librairie Felix Alcan, Paris, 1934 pp. 64-68. He states in one section: "Une etude approfondie, qui porterait sur ce probleme, serait naturellement necessaire, sous le regime de l'Entente International, pour fixer un prix mondial satisfaisant du ble."

were taken from the data of the present study.[4] The amount of labor available was assumed to be that actually found on the farms (see Table IV). The length of time available for each of the seeding and the harvest seasons for this area, was derived from information in the monthly crop reports of the publications Branch of the Manitoba Department of Agriculture.[5] The time period was based on monthly reports for the years 1941 to 1951 inclusive. It was found on the average that the length of time between the beginning and the end of the seeding and harvest seasons was 38 days and 52 days respectively. It was assumed that on the average 25 days out of the 38 days would be actually available for seeding operations.

For the harvest season it was decided that 27 days would be actually available for harvesting operations. Adverse weather conditions will naturally prevent the full season from being available for actual seeding and harvesting operations. For the purposes of calculating the number of man-hours available, it was assumed that a day would consist of ten hours both for seeding and for harvest.

Accordingly, (Table XXVII) the maximum acres that could be handled in the seeding season for the half-section, three-quarter section and one section farms were found to be respectively 244 acres, 379 acres and 484 acres. In a similar manner it is shown that the maximum number

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4/The labor inputs per acre were based on the average inputs for wheat, barley, oats and flax. The aggregate figure for labor inputs per acre reflects both the average labor inputs for each crop and the relative importance of each crop as measured by relative acreage.

5/Information supplied by the Publications Branch of the Manitoba Department of Agriculture, 1951.

of acres that could be harvested were 189 acres, 272 acres and 307 acres respectively as size of farm was increased.

TABLE XXVII

Data Used in Calculation of Maximum Size of Farm for Each Season

	½ Section	¾ Section	1 Section
Actual days available for seeding	25	25	25
Actual days available for harvesting	27	27	27
Man-equivalent of available labor per farm	1.25	1.55	1.82
Man days of available labor for seeding	31	39	46
Man days available labor for harvest	32	40	47
Man-hours per acre for seeding	1.28	1.03	.95
Man hours per acre for harvesting	1.69	1.47	1.53
Maximum acres that could be handled in the seeding season	244	379	484
Maximum acres that could be handled in the harvest season	189	272	307
Actual acres handled	137	209	238

With a given type of farm organization which prevailed in the area under study, a given labor force and a given amount and kind of machinery, it can be noted that the labor requirements of the harvest season determine the maximum size of farm. It is to be further observed (Table XXVII) that in every case the number of acres actually handled is below the maximum acres that could be handled as determined by the harvest labor requirements.

There are several ways of overcoming the limitations set by the relatively high labor requirements of the harvest season. The investment in equipment per acre and the time limitations for the seasonal operations present a problem of what is the best combination of land and equipment for the crop producing unit. The time limitations are the least amendable of all the factors setting the upper limit to the amount of crop that can be handled. The risk of severe loss involved makes it undesirable to extend an operation such as seeding or harvest beyond certain critical time periods. Some farmers can handle an acreage well in excess of the average by working longer hours and also by working a greater number of days. Such a practice in the case of a wet or backward harvesting season would subject such farmers to tremendous losses.

One could extend the number of acres that could be handled by increasing the size and quantity of equipment. However, a balance must be struck between keeping quantity of equipment and consequently the investment, to a minimum and yet having enough equipment to keep up the timeliness of the work. A minimum investment is necessary to avoid a heavy burden of overhead per acre and yet there must be sufficient machinery to avoid the penalties which come from performing the various operations after the optimum time has passed. Some farmers in the present study had enough equipment to enable them to expand their crop acres but it is desirable in an area such as Hamiota, which is characterized by extremely variable weather conditions, that a reserve or an excess capacity be maintained - i.e. an excess machine capacity in normal years but a capacity which is fully utilized in seasons of adverse weather.

Hired labor in addition to the total labor available on the farms, might serve to allow an increase in the acres of crop that could be handled in the harvest season but such gains would be small. Generally an addition of hired labor would entail an increase in the amount of machinery needed if the additional hired labor is to be effectively used in the crop harvesting period because it is seldom practical to depend on working a combine or any other harvesting machine on a 24 hour-a-day basis.

Custom services play a fairly important role in the maximum amount of acres that can be handled in a given period of time. Some farmers in the Hamiota area handled an acreage that would represent an excess in relation to their available machinery and labor, by depending on custom services. Many small farmers owned a combine for example, which was too large for their own farm but which was used part time on the farms of those who had a crop acreage which they could not handle with their labor and equipment alone.

It can be concluded from the results established in this section that the strategic factor influencing size of farm is that of mechanization in the harvest season. Considerably more crop acres can be handled on these farms during the seeding season than in the harvest period. If size of farm is to be expanded, it will depend heavily on the advances in mechanization of the harvest operations. In earlier times a reasonably large acreage could be cared for in the harvest season by virtue of the availability of migratory, seasonal labor. In current times with the high cost and shortage of available harvest labor, more and more dependence will be placed on mechanization of harvest operations.

Certainly, the combine and motor truck have revolutionized the methods of harvesting, allowing at the same time, a considerable expansion in the optimum size of farm.

CHAPTER VI

SUGGESTIONS FOR FUTURE STUDIES ON THE DYNAMICS OF LABOR AND MACHINERY ALLOCATION IN CROP PRODUCTION

Because the present study was confined to only one year, it is unable to offer any empirical data for the analysis of the dynamic situation of labor and machinery allocation resulting from year to year changes which impinge on crop production. However, the results of the present one-year study do offer suggestions as a guide for future studies of this sort. A study on the dynamics of resource allocation in crop production must be based on data covering a series of years. In this way one can properly evaluate the effects of those changes associated with a succession of years; changes such as variations in weather from year to year, technological changes and any other physical factors which are given for any one year but which are subject to change from one crop production period to another.

It will be the purpose of this section to show how the dynamic conditions which attend the operations of a farm in crop production give rise to conditions of uncertainty which confront the farm operator in his decision making. It will be pointed out how conditions of uncertainty affect efficient resource allocation, with special emphasis on allocation of labor and machinery in crop production. It will then be noted how a farm operator may offset some of the disadvantages of uncertainty, by incorporating flexibility into the resource structure of his farm.

A. General Discussion of Risk and Uncertainty

A dynamic situation is one where not only the relationships between economic variables are changing but the probability distribution of the relationships are also changing.[1] This is to say that under such circumstances there is no perfect knowledge or foresight of future events. The future is objectively undefinable.[2]

To achieve a clearer picture of the significance of dynamic conditions, one must study the entrepreneur who is faced with an indeterminate future when he makes decisions and translates these decisions into action within his firm. Professor Knight elects to define the effects of an uncertain future in terms of risk and uncertainty to the entrepreneur. He states: "The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known (either through calculation a priori or from statistics of part experience), while in the case of uncertainty this is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique."[3] In other words he defines risk as a measurable "uncertainty"

1/For a more exhaustive treatment of dynamic theory in its relation to economic analysis in farm management see: Johnson G.L., "Needed Developments in Economic Theory as Applied to Farm Management," Journal of Farm Economics, Nov. Proceedings, 1950, pp. 1141 and 1151-1156.

2/This means that no objective prediction can be made of the future occurrence of events, based on knowledge of the past or of knowledge of possibilities of the future.

3/Knight F.H., Risk, Uncertainty and Profit, Reprint from London School of Economics and Political Science, 5th Ed., 1940. pp. 233.

and uncertainty proper, as an unmeasurable one. It follows from this that risk situations contain an actuarial base for removing the risk. (This is actually the case in the operations of a life insurance company). For purposes of the present study, another writer[4] has conveniently refined this concept of risk and uncertainty. He notes that risk and uncertainty may be due to the major influence of change in market prices, technical or technological conditions. Only the technical and technological conditions are of immediate concern here.[5] When there is a known probability distribution of the technical and technological changes which reflect in various production functions, it is described as risk. If there is no known probability distribution of the changes in the production function which result from technical or technological changes, it is described as uncertainty. For purposes of illustrating changes in the production function of grain production due to technical or technological reasons, only the case of uncertainty will be treated here.

B. <u>The Farm Firm and Conditions of Uncertainty</u>

How does the entrepreneur act in face of conditions of uncertainty? He will continue to make decisions and to translate these

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4/Tintner G., "The Theory of Production Under Non-Static Conditions," Journal of Political Economy, Oct. 1942 p. 646.

5/Tintner describes technical changes as due to the uncontrollable influence of weather, errors etc., and technological, as changes in the production function of the firm resulting from innovations. This definition will be used throughout the present section.

decisions into action within the firm. His decisions must be based on a subjective [6] evaluation of an uncertain future. It is perhaps obvious that the function of prediction on the technological side of production itself inevitably devolves upon the producer. In carrying on rational action he must attempt to anticipate the results of any plan which is committed for operation. Any increase in the time length of the production process will correspondingly increase the uncertainty involved. Because of the constantly changing conditions and the uncertainty which surrounds the farm firm, the farm itself may be regarded as a product of dynamic conditions.[7] The static theory of the firm would see a farmer operating more efficiently than is usually the case. It would prescribe larger farm units and better methods of production. The static theory fails to take account of the conditions of uncertainty which confront the farm entrepreneur and which leaves him often reluctant to follow out in practice all that the static theory would indicate. A dynamic theory is needed to explain the impact of technical and

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6/Tintner ibid., describes subjective evaluation as the act of an individual in estimating the probability of the probabilities of certain events taking place in the future.

7/For a more complete discussion on the theory of the farm firm in its relation to dynamic conditions see: Schultz, T.W. "Theory of The Firm and Farm Management Research", Journal of Farm Economics, August 1939. pp. 570-586.

technological uncertainty on the farm firm.[8/]

C. Uncertainty and Its Relationship to Labor and Mechanization in Crop Production

It will be shown here how both technical and technological changes affect the amount of labor and mechanization in crop production. The lines A, B and C represent product contours, all of which are of equal value in terms of output and are expressed as acres of crop produced (figure 4). In other words all lines (A, B and C) represent the same amount of crop produced with varying amounts of labor and machinery. Any particular line (product contour) reflects the marginal rate of substitution of labor and machinery in crop production. The higher the product contour the less superior the technique of production. In the above diagram the best production function is represented by product contour A.

In figure 4 product contour B is allowed to represent the production function at any given time in crop production. Product contour C represents the production function in crop production in any year apart from the given year. It rises above contour B because of adverse conditions in crop production. Wet weather causing delays and

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8/Williams, D.B., "Application of Economic Theory to Farm Management Research." Journal of Farm Economics, Nov. Proc. 1951. p. 1054 Williams states in this article: "The attitude of the farmer toward risk situations, and his judgment of them, are both important factors influencing not only the type of farming adopted, but also the production methods used and the willingness of the farmer to approach the intensive margin envisaged in static economic analysis."

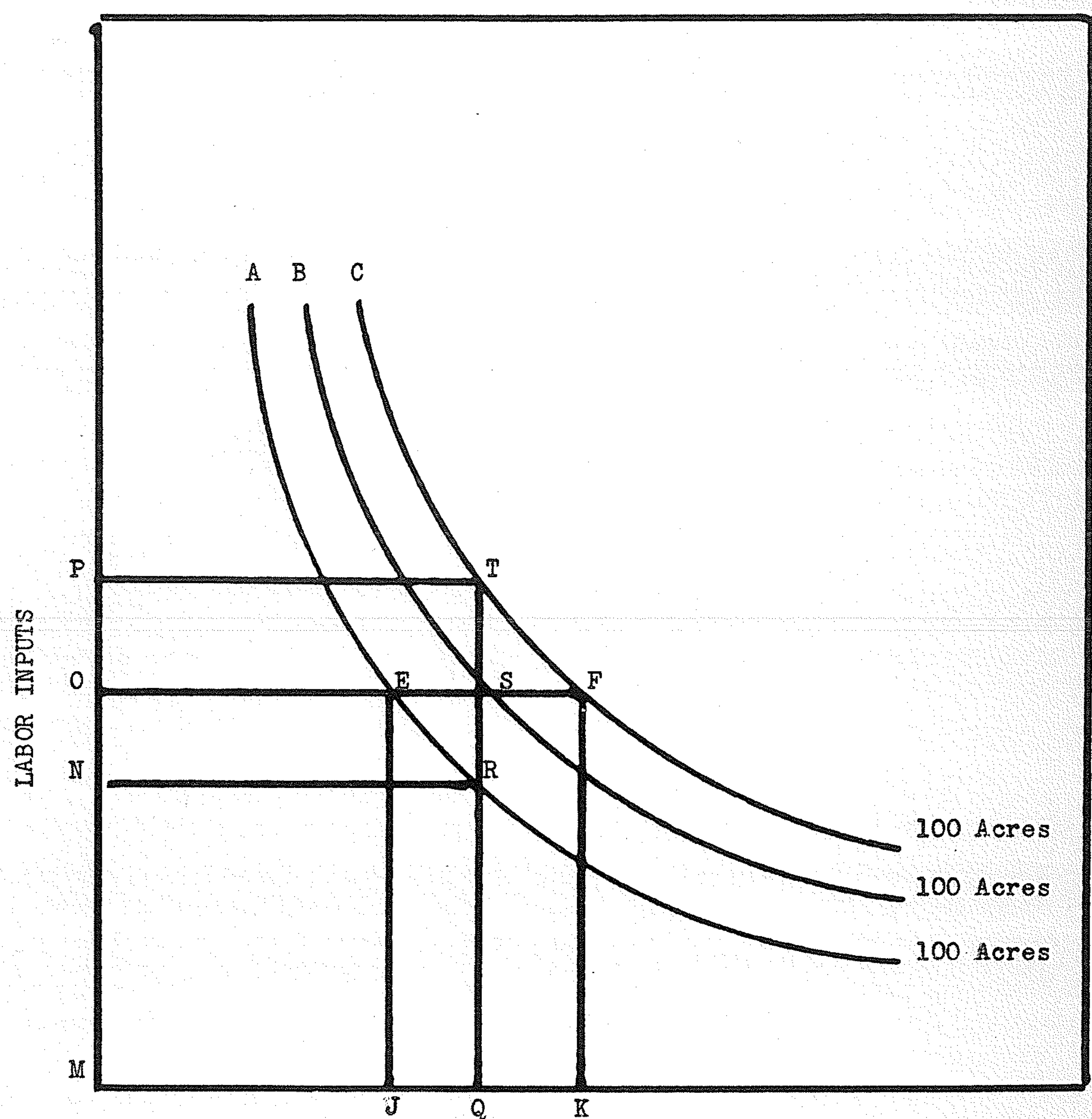

Figure 4

Hypothetical Combination of Labor and Mechanization in Crop Production and the Effects of Technical and Technological Changes slower operating speeds of machinery in crop production will cause the contour to rise. An increased growth of weeds in any one year will also cause the contour to rise. Product contour A represents the production function in crop production in any given year which is more favorable than in the base year represented by contour B. Technological innovations will almost invariably cause the product contour to shift downward and to the left. The change over from the threshing machine to the combine harvestor is such an example. The advent of weed spray in crop production would also cause the product contour to shift downward.

Whenever the product contour shifts upwards it means that more labor and/or more machinery is required to care for the same acreage of crop. Conversely a shift downward in the product contour means that less labor and/or machinery is required for the same acreage of crop. In other words technical and technological changes will cause the product contours to shift one way or the other. The farmer represented by product contour B in any given year is confronted with uncertainty in the ensuing years. He cannot forecast the technical or technological changes of the future and as a consequence cannot anticipate which product contour will represent his farm in the following years. The practical implications of such a situation is that labor and machinery requirements will vary to a greater or lesser degree from year to year. It means that if a farmer is operating at an optimum capacity in the year represented by contour B, that if in the following year his production is represented by contour C, there will be a strain on his labor and machinery resources.

On the other hand if in one of the ensuing years the product contour shifts to position A, the farmer who formerly operated at an optimum with respect to his labor and machinery, will now have an excess capacity. If the latter shift downward is due to a technological change, it will be an irreversible type of move, and the farmer in question will have an excess of labor and/or machinery until he either increases his size of farm or reduces the quantity of labor or machinery at his command.

It can readily be seen why a static theory of analysis of the farm firm fails to recognize the impact of uncertainty of the future on the farm entrepreneur. The static theory of analysis prescribes an optimum position for the farm firm and would tend to call anything that deviated from this ideal, a condition of inefficiency in resource allocation. The static theory would advocate a size of farm that would make maximum use of labor and machinery under normal conditions. How does this apply to the farm entrepreneur who is confronted with an indeterminate future - technical and technological uncertainties? The farmer has complete flexibility in the planning stage of his farm, but once he has committed himself to fixed resources how will he be able to adjust to technical or technological changes that occur from year to year? The farmer who is planning to set up a crop-production unit must try to reconcile his present type of operation with changes that might accompany an uncertain future. His size of farm, amount of machinery and availability of labor must be organized so as to be least adversely affected if technical or technological changes do occur.

D. Measures to Counteract Technical and Technological Uncertainty

The problem is one of the optimum combination of size of farm, labor and machinery in crop production under conditions of future uncertainty. The farm firm is notoriously slow in its adaption to technical or technological changes and as a consequence any static analysis of the farm usually reveals a gap between the prevailing type of organization and that which appears to be the optimum. To facilitate the speed with which a farm firm can adapt itself to technical or technological changes in crop production it is proposed that greater flexibility is needed in the resource inputs of the farm unit.

A major portion of the inputs on a farm are of a fixed nature in the short run. The labor supply which is composed almost entirely of family labor is quite inflexible. The size of farm is of a very rigid nature in the short run. Similarly the greater part of machinery and equipment in crop production is generally quite invariable in the short run. Accordingly, the problem is one of trying to insert some flexibility[9/] of operation into a farm unit whose structure is characterized

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9/For the conceptual background of the application of flexibility in farm resource allocation see: Heady, E.O. "Uncertainty in Market Relationships and Resource Allocation in the Short Run", Journal of Farm Economics, May 1950, pp. 240-257.

by these rigidities of resource inputs.

In figure 4 it is shown what adjustments in labor and machinery are required when technical or technological conditions cause a shift in the production function of the grain producing farm unit. For example a shift in the product contour from position B to position C demands an increase in either machinery or labor or both. If the amount of machinery is fixed at quantity MQ then an increase of ST in labor supply is necessary. If, on the other hand, the labor supply is fixed at MO, it will be necessary to increase machinery supply by the amount SF. In the former case of labor, its supply might be expanded by the operator working longer hours, by withdrawing labor from enterprises other than grain or by hiring additional labor. If labor supply is fixed then machinery supply might be increased by custom hiring of machines or by purchasing additional machinery. The purchase of additional machinery is hardly warranted if the shift in the product contour is due to adverse weather which may happen only once out of every few years.

Suppose the product contour shifts from position B to position A (as a result of technological innovations) it can be seen that less machinery and/or less labor is needed for a given output of crop. It has been noted previously that a shift from product contour B to product contour A if due to technological innovation, is generally of an irreversible nature. This means that either excess of labor or machinery or both must be eliminated by increasing the size of farm or by reducing the amount of the excess resource on hand.

Flexibility in resource use has been advocated as a means of counteracting unexpected changes that might occur from year to year in the production function of a grain farm. The idea is to allow the farm unit to accommodate itself to these changes with the least possible delay and with the least amount of idle time or loss of crop. The amount of flexibility that should be incorporated into the resource structure of the farm firm will depend in large part on the degree of variability of the technical and technological changes, that impinge on the farm unit.

In other words, the greater the degree of variability, the greater the necessary flexibility in resource use. For example, a farm situated in an area of highly variable weather conditions will certainly require a greater degree of flexibility in its resource structure than a farm which is situated in an area of fairly uniform weather conditions. The latter farm would be utilizing its labor and equipment at a more constant capacity than the former farm. The grain farm in a region of highly variable weather will be characterized by a strain on its labor and machinery in one year and in another year underused capacity in the form of underemployed labor and idle machinery. This sets up a challenge to the operator of this type of farm. It must be so organized internally, that in years of adverse weather, labor and equipment for grain production can be withdrawn from less profitable enterprises and in years of exceptionally good weather, potentially idle machinery and labor can be employed in enterprises which can be easily expanded.

CHAPTER VII

SUMMARY

The objectives of the present inquiry were accomplished. Labor inputs per acre were determined for the half-section, three-quarter and one section size farms for the seeding season, harvest season and the entire crop season. The substitutionary relationship between labor and machinery in crop production was established by stratification of the farms according to aggregate size of machinery and by multiple regression analysis. Efficiency of labor use in crop production was evaluated between the various sizes of farms by acceptance of a minimum of labor inputs per acre as the criterion of efficiency.[1/]

In the determination of labor inputs per acre for the different sizes of farms during the seeding season it was found that there was a general tendency for labor inputs per acre to decline as size of farm was increased in all cases except that of barley. It was found that the three-quarter section group of farms had the least labor inputs per acre for barley production. It was established that this was the result of the three-quarter group having on the average, larger cultivators and discs than the one section group and also carrying out less intensive preparatory work for the barley seeding

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1/A minimum of labor inputs per acre does not necessarily imply economic efficiency (i.e. minimum production costs or maximum net returns) for the high overhead of the large machinery may offset the savings of labor accomplished by the use of the larger machines. However, for the purposes of this study a minimum of labor inputs per acre was set up as the criterion of labor efficiency.

operations.

A comparison was made of the labor inputs per acre for the harvest season for the three sizes of farms. It was observed that the three-quarter size group required generally, the least labor inputs per acre. This was the result of the three-quarter group having on the average, the largest size combines and swathers. When a comparison was made between the labor inputs per acre for the different crops it was noted that wheat and barley generally required less labor per acre for harvesting than in the case of oats. This situation resulted from the greater use of the binder and threshing machine to harvest oats, the oat straw being used for animal feed.

In the determination of labor inputs per acre for the entire crop period account was taken of the total labor expended on crop production for the entire crop period. This labor included besides the labor expended directly during the seeding and harvesting, all labor involved in summerfallow work, picking and spraying weeds, spreading manure, stone picking and any other tasks not directly connected with the seeding and harvesting operations but which were in some way related to crop production during the year. It was found that generally the three-quarter group showed the least labor inputs per acre for all crops except barley. The reason for the three-quarter group having higher labor inputs per acre for barley production for the entire crop period as compared to the one section group is explained by the fact that a greater proportion of barley in the three-quarter group is sown on summerfallow; the summerfallow work required considerable labor inputs per acre.

The effects of increased size of machinery on labor inputs per acre was determined by two methods: (1) grouping farms according to aggregate size of machinery and determining the labor inputs per acre within each group (2) by multiple regression analysis. Both methods served to show that as size of machinery was increased, labor inputs per acre tended to decline. This result points out the substitutionary relationship which exists between labor and machinery in crop production. The multiple regression analysis also showed that, apart from size of machinery, when size of farm was increased, labor inputs per acre tended to decline. While none of the available data of this study could suggest specific reasons for the negative relationship between size of farm and labor inputs per acre, it does point out the need in further studies of this kind for additional data on factors associated with scale of farms which effect greater labor efficiency as scale increases. Multiple regression equations were established so that one could predict on the basis of the given crop production practices of this area and with a certain aggregate size of machinery and a certain size of farm, the labor input per acre for seeding and for harvesting. The standard error of estimate shows the reliability of such estimates.

An analysis was carried out on the variations which occurred in machinery size and labor requirements per acre within a given size-group of farms. The results suggested considerable variation in aggregate machinery size and in labor inputs per acre for both the half-section and the three-quarter section groups of farms. The significance of this marked variation is that labor efficiency varies not only with a change in size of farm but also within a given size-group of farms. This implies that any measures directed at increasing labor efficiency in crop production must not only consider change in size of farm but also practices within a given size of farm.

One of the more striking aspects of the present study was the analysis of hand labor in crop production. It was shown that quite a considerable proportion of the total labor expended in crop production was of the nature of labor expended apart from the actual operation of the field machine. Seeding operations involved a significant amount of hand labor, ranging around 25 per cent of the total labor. Harvest operations involved a surprisingly large percentage of hand labor, ranging anywhere from a low of 46 per cent for wheat harvesting operations to a high of 66 per cent for oat harvesting. A large percentage of the hand labor in harvesting operations was due to the great number of farms still using the binder, stooking and the threshing machine to harvest part or all of their crop. The remainder of the hand labor involved non-mechanized tasks such as repairing and servicing machinery, stone picking, grain handling, repairing granaries etc. This suggests that a considerable reduction in labor inputs can still occur. Two major suggestions are offered as a method of bringing about this reduction. Many tasks in crop production can be more fully mechanized. There is considerable room for expansion in the use of combines, mechanical grain-loaders, and larger sizes of existing types of equipment. The time spent in tasks which do not lend themselves to mechanization can be reduced significantly by appropriate farm work simplification techniques.

The present study has provided the physical input-output data which must be the major prerequisite to any economic analysis of efficient resource allocation in crop production. The results established apply only to conditions similar to those under which this study was carried out - a certain soil type, given climatic conditions and a given type of farm organization. This implies the need for similar studies on other soil types, differing climatic conditions and varying types of farm organizations.

Crop production still involves relatively large labor requirements. Mechanization has played a very important role in reducing labor requirements but this study has revealed that still further reductions could occur on the farms of the Hamiota area. If these farms are to maximize their returns it is imperative that more attention be devoted to ways of reducing the labor requirements of crop production while at the same time minimizing the high overhead of machinery investment.

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APPENDIX

A. Calculations for the Aggregate Machine Size Index

The aggregate machine size index was designed for the purpose of giving a common expression of size to the aggregate of machinery which exists on any given farm. This index was designed to reflect both the size and relative importance of each machine used on the farm. Comparisons can be made between farms of their machinery used, through the use of the aggregate machine size index. The objective of setting up this index was to allow facility in the multiple regression analysis.

The aggregate machine size index as constructed here, does not take account of differences that might occur from farm to farm in the frequency of operation as performed by any given type of machine. It was decided on the basis of the results established in Table XI, that frequency of operation of the various machines did not vary significantly over the sample of farms studied. With this assumption it was decided that the aggregate size of machinery would adequately reflect the relationship between size of machine and labor inputs per acre in crop production.

1. Establishment of size base for each type of machine

It was necessary to find some base size against which to relate the various sizes of any given type of machine. Accordingly, it was decided that the average size of each type of machine as calculated over the entire sample of farms would be used as the base size.

TABLE XXVIII

Average Size of the Various Types of Machines as Calculated Over the Entire Sample of Farms

Plow	2.8 feet	Cultivator	10.4 feet	Drag Harrows	24.7 feet
Drill	6.6 feet	Packer	12.6 feet	Oneway	6.6 feet
Discs	11.6 feet	Rod Weeder	10.0 feet	Binder	8.1 feet
Spr. Tooth Cultivator	12.6 feet	Swather	11.5 feet	Discer	12.2 feet
		Combine	8.9 feet	Thresher	25.7 feet

2. Determination of the relative importance of each machine

The relative importance of each machine used on a given farm was determined by assigning a weight to the machine. The weight for each machine was calculated by determining the percentage of time the machine was used as compared to the total time used by all machines. The resulting percentage number was used as the weight of relative importance of that particular machine.

3. Calculation of the size index for a given machine

$$\frac{\text{Actual size of given machine expressed in feet}}{\text{Average size of the same type of machine}} \times \text{weight number}$$

4. Calculation of the aggregate size index

The calculation of the aggregate machinery size index merely involved the summation of all the separate machine indexes for the given farm.

TABLE XXIX

Actual Example Used in Calculation of the Aggregate Machinery Size Index for an Individual Farm for the Seeding Season

Type of Operation	Size of Machine	Acres	Man Hrs.	Tractor Hours	Percentage of Time for Each Operation (Trac.Hrs. ÷ Total Trac.Hrs.)
Cultivation	8'	115	43	39	18.0
Harrow	21'	370	55½	50	24.0
Sow	10'	108	34	23	11.0
Oneway	4'	100	111	100	47.0
Total			243½	212	100.0 %

Machine Size Index

Cultivator	$\frac{8}{10.4}$	x	18	=	13.8
Harrows	$\frac{21}{24.7}$	x	24	=	20.4
Seeder	$\frac{10}{11.8}$	x	11	=	9.3
Oneway	$\frac{4}{6.6}$	x	47	=	28.5
					72.0

Aggregate machine size index for this given farm = 72.0

This farm can be compared to a farm with an average size of machinery whose aggregate machine size index = 100.0

B. Calculation of the Labor Inputs Used in the Multiple Regression Analysis

The labor inputs per acre used in the multiple regression analysis represents the labor associated with the actual operation of the machine in field work. This is expressed in terms of tractor hours as reported in the present study. The time spent in actual operation of self-propelled equipment such as the combine-harvestor which was not tractor drawn, was still reported as tractor hours for purposes of the labor input calculation.

The labor associated with actual operation of a field machine (expressed as tractor hours) was chosen instead of the total man-hours which included not only actual operation but repair, maintenance and

TABLE XXX

Labor Inputs per Acre for the Seeding Season

Type of Crop	Acres Sown	Total Tractor Hours
Wheat	35	28
Barley	38	95
Oats	25	68
Flax	10	21
Total	108	212

Average tractor hours per acre $= \frac{212}{108} = 1.96$

and other tasks incidental to the operation of a machine, because it represented labor inputs which were a direct function of the aggregate size of machinery. In that the multiple regression analysis was adopted in this study to show the direct substitutionary relationship between labor and mechanization, it was felt that tractor hours rather than total man-hours would more adequately represent the substitutionary relationship.[1/]

1/Labor inputs in crop production apart from actual operation of the machine are described elsewhere in this report as hand labor. See page 80. This hand labor does not necessarily show a correlation with aggregate size of machinery.

The figure 1.96 represents the tractor hours per acre for the entire crop sown on the individual farm. A similar calculation was carried out on every farm, so that each farm would have a figure for average tractor hours per acre for the entire crop.

D. Calculation of the Man-Equivalent Rating

One man-equivalent as defined in this study is equal to eight months of male adult labor during the crop production period. The labor of women and school children (12-16 years of age) who participated in the crop production operations in any way was expressed in terms of the man-equivalent of labor. Both women and school children were arbitrarily assigned a labor value, equivalent to one male adult month. While the transformation of labor was an arbitrary one, it was based on observations of the sample of farms studied during the summer. It was generally observed that women and school-children did make a valuable contribution to the farm labor picture during seasons of high labor requirements but their contribution was confined to the lighter tasks and was generally of a limited duration.

E. Calculations for Construction of the Optimum Size of Farm

The labor inputs per acre used in construction of the optimum size of farm were based on the total man-hours per acre. This included labor on the actual operation of the machine and in addition all labor described elsewhere in this study as hand labor.

The amount of available labor was taken from the data as derived in Table IV. It was arbitrarily assumed that the number of hours worked during a day would be ten. Of course in times of peak labor requirements the length of working day can be expanded especially during the seeding period. In the harvest season the length of effective working day is quite limited due to the favorable circumstances required by the combine harvestor. In general however, it is believed that the ten-hour working day is quite representative.

The length of the seeding and harvesting seasons in the Hamiota area was determined from data in the monthly crop reports submitted from that area to the Manitoba Department of Agriculture.[2/] The determination of length of season was based on data over the last ten years, 1941-1951 inclusive. Careful observation of the monthly reports seemed to indicate that only about one-half of the respective seasons was available for actual crop work. Adverse weather causes much delay in crop operations, especially during the harvest season. This was very evident during the harvest season in the year of this study.

2/ The information was derived from the monthly crop reports of the: Publications Branch, Manitoba Dept. of Agriculture.

FARM OF FOR THE WEEK ENDING SATURDAY, ______ 195__

WORK DONE (Give size of machine used)	CROP									
	Persons Doing Work	Acres	Hours		Acres	Hours		Acres	Hours	
			Man	Trac.		Man	Trac.		Man	Trac.

NAME OF PERSONS doing any farm work during the week.	ALL FARM WORK	
	Days	Hours

OTHER WORK DONE	
On repairing machinery	hrs.
Work on livestock	%
On permanent improvements other chores, etc.	%
On Farm business activities	%

WORK CONTRACTED or custom hired	Amt.	Price	Cost