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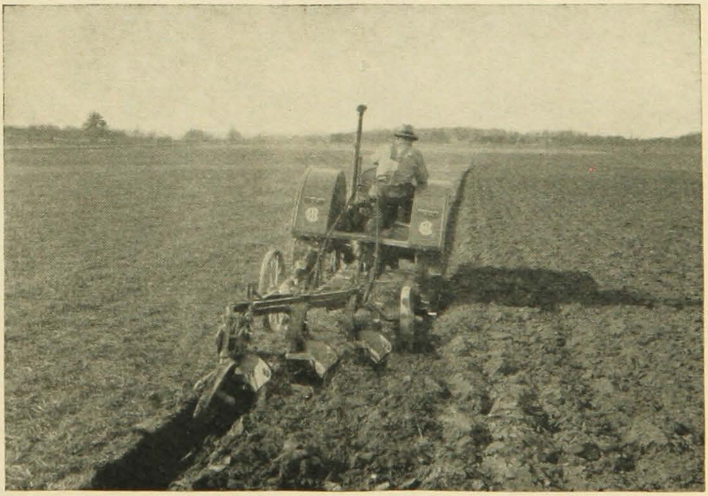
THE FARM TRACTOR IN MINNESOTA

By

A. J. SCHWANTES
DIVISION OF AGRICULTURAL ENGINEERING

AND

G. A. POND
DIVISION OF AGRICULTURAL ECONOMICS



UNIVERSITY FARM, ST. PAUL

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THE FARM TRACTOR IN MINNESOTA

A. J. Schwantes and G. A. Pond

INTRODUCTION

During the last ten years the importance of the tractor as a source of power on Minnesota farms has steadily increased. In 1920 there was one tractor to 11 farms in the state; the present ratio is about 1 to 3.8. There are about 2¼ tractors for each thousand acres of crop land. The increase in the use of tractors is important because power represents from 10 to 40 per cent of all costs of producing the common Minnesota farm crops, not including the land charges. Farmers who have tractors are interested in using them to best advantage; while others are asking whether or not a tractor would be a profitable investment for them. The material presented in this bulletin represents some of the experiences of 291 tractor operators in Minnesota. These men operated farms of different types and sizes, located in different parts of the state. It is hoped that their experience may be of some assistance to other owners in operating their tractors to better advantage and to non-owners in deciding whether or not to purchase a tractor and the proper size and type to select.

It is impossible to make any generalizations regarding these problems that will be applicable to any group of farms. Each farm presents a problem in itself. It is necessary for the operator to apply what information is available relative to the use of tractor power to his own particular conditions and then make his own decision.

This report is concerned primarily with the tractor and its effective use as a source of farm power. Little attention is given to other forms of mechanical power or animal power except in their relation to the farm tractor. The authors recognize the wide variation in the economy and effectiveness with which animal power is used on farms. This, in turn, affects the choice of power for any given farm. However, most farmers have had life-long experience with horses. Less than 10 per cent of all Minnesota farmers, on the other hand, have had as much as ten years experience with tractors. This publication is, therefore, intended to supplement the experience that Minnesota farmers already have had with animal power, with the experiences of a group of farmers who are using tractor power. This should aid in choosing the most effective kind or combination of power for any given farm as well as assist both present and prospective owners in utilizing their tractors to best advantage.

POWER SUPPLY ON MINNESOTA FARMS

Horses and Tractors

The kind and amount of power in use on farms in Minnesota have been changing rapidly during the last few years. Of major importance in this change is the decrease in the number of horses and mules and the increase in the number of tractors. The numbers of each for the ten-year period, 1921 to 1930, inclusive, are shown in Table 1.

Table 1

Horses, Mules, and Tractors on Minnesota Farms, 1921 to 1930, Inclusive

Year	Horses and mules				Tractors‡	Total available drawbar horse power§
	Number†	Under three years of age*		Number three years of age and over		
		Number	Per cent of total			
1921	915,000	105,454	11.5	809,546	16,679‖	942,978
1922	897,000	75,681	8.4	821,319	18,770	971,479
1923	862,000	60,829	7.1	801,171	19,714	958,883
1924	848,000	60,325	7.1	787,675	23,226‖	973,483
1925	840,000	62,027	7.4	777,973	26,739	991,885
1926	824,000	68,764	8.3	755,236	29,117‖	988,172
1927	817,000	73,746	9.0	743,254	31,496	995,222
1928	801,000	76,413	9.5	724,587	34,965‖	1,004,307
1929	786,000	65,135	8.3	720,865	38,435	1,028,345
1930	771,000	66,619	8.6	704,381	48,457¶	1,092,037

* These data were obtained from reports of the Minnesota Tax Commission for 1922 to 1930, inclusive.

† Kirk, Paul H. Minnesota Annual Crop and Livestock Statistics, Minn. Dept. of Agr., 1923-24, Bull. 42, p. 33; 1925-26, Bull. 55, p. 35; 1928-29, Bull. 5, p. 33.

‡ Kirk, Paul H. Minnesota State Farm Census, Minn. State Dept. of Agr., 1921-22, Bull. 22; 1923, Bull. 32; 1927, Bull. 61; 1929, Bull. 3.

§ These figures are based on the assumption that the average tractor is equivalent to 8 work horses.

‖ Estimates.

¶ Fifteenth Federal Census. 1930.

The number of work horses has decreased from 809,546 in 1921 to 704,381 in 1930, a total of slightly over 13.0 per cent. With the exception of 1921 and 1922, the number of colts has remained about the same during the entire period and the tendency has been for the ratio of colts to horses to increase slightly. This indicates that Minnesota farmers are making provision for a future supply of animal power altho this ratio is not large enough to maintain the present number of work horses in years to come.

The increase in tractors during this period has been much less than the decrease in horses and mules—31,778 tractors have been added, whereas the number of work horses and mules has been reduced by 105,165. The increase in tractors is 191 per cent.

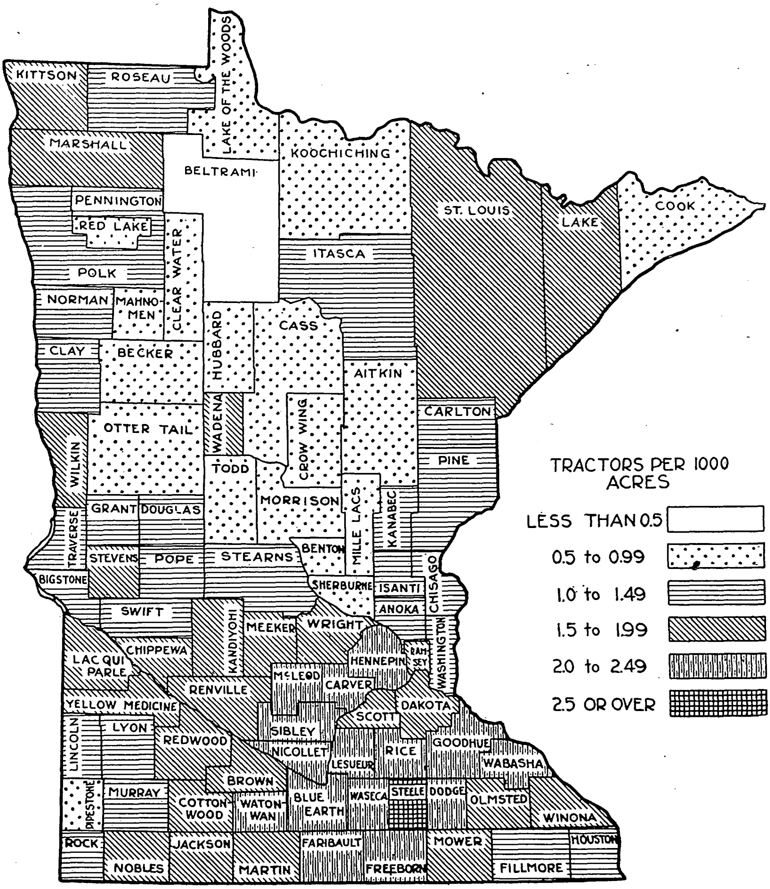

Fig. 1. Tractor Distribution in Minnesota by Counties Based on Acres in Crops, 1929

The concentration of tractors based on acres in crops is relatively high in southeastern Minnesota because the average size of farms is smaller than it is in southwestern or northeastern Minnesota. Because the average crop acreage per farm is low in many of the counties in northeastern Minnesota, the number of tractors per 100 acres appears high there also.

Figure 1 shows the number of tractors for each 1,000 acres of crops in each county. The concentration in some of the southeastern counties is relatively high on this basis, because the average acreage per farm in these counties is relatively small and the percentage of farmers owning tractors is relatively high. A high concentration is also shown for some of the northeastern counties because of the small number of crop acres per farm in the cut-over areas and of the farm tractors that are used for such operations as land clearing, lumbering, and road work. The average for the state is 2¼ tractors for each 1,000 acres of crop land.

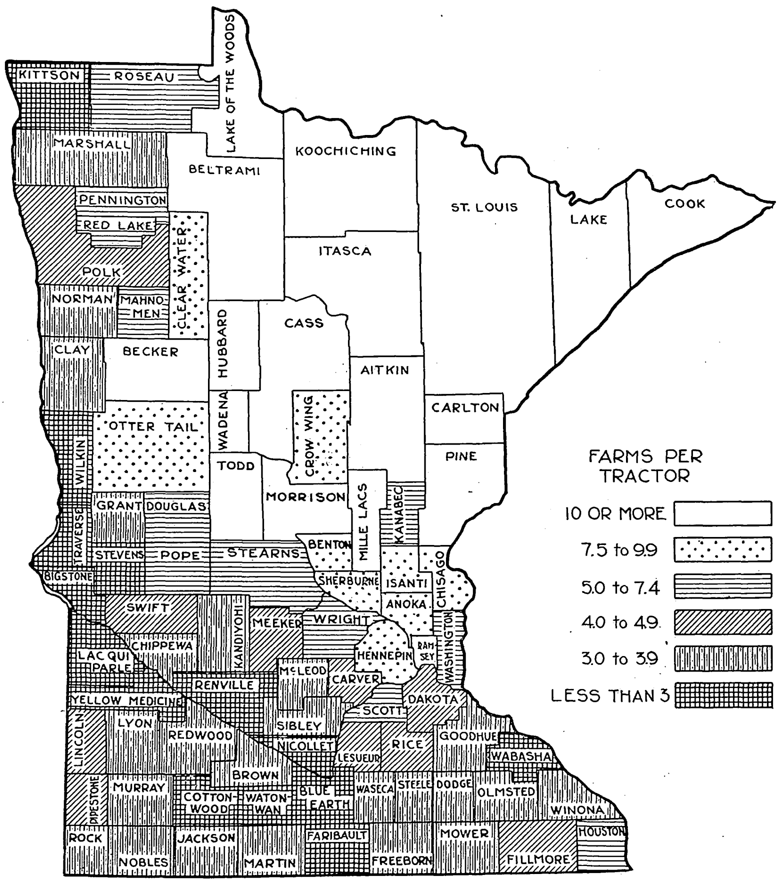

Fig. 2. Tractor Distribution in Minnesota by Counties Based on Number of Farms, 1929

The number of tractors in relation to the number of farms is about the same across the southern half of the state and in the extreme northwest. There are relatively more farms without tractors in the cut-over sections of northeastern Minnesota than in other parts of the state.

In Figure 2 the tractor density for each county is shown on the basis of the number of farms regardless of size. Some of the northwestern counties have a relatively large number of tractors on this basis. This is also true of some of the counties in the dairy section of the state. There is one tractor for each 3.8 farms in the state.

The data in Table 1 show a gradual but definite trend toward the increased use of mechanical power and a decrease of animal power. It is important to determine if this change in form of power results in a change in total quantity of farm power available.

Because the ratio of animal power to mechanical power on Minnesota farms is changing constantly it is desirable to establish a unit of comparison that is common to both forms. The farm tractor is purchased primarily for drawbar power. A tractor is comparable with horses only to the extent of the drawbar work it is capable of doing.

The figures in Table 1 indicate that 105,165 horses have been replaced by 31,778 tractors. This is one tractor for each 3.3 horses. Cavert[1] found, in his study of power on Minnesota farms, that the average tractor was replacing 3.1 horses, and it will be shown later in this discussion that the average tractor in this study replaced 3.6 horses. It must be remembered also that the tractor is not the only mechanical device that is affecting the use of horses on the farm. The automobile is a very important factor, also the motor truck. Hart,[2] in his study of the motor truck on New York farms, shows an average of 1.8 horses displaced per farm on 189 farms operating trucks. The tractor is not used to its optimum capacity on most farms. Horses are retained when the tractor is purchased and used for operations to which the tractor is not adapted or for which more or less special equipment would be necessary if the tractor were to be used advantageously. As a result the average tractor farmer has available more drawbar power after he has the tractor than before.

It is shown later in this discussion that 7 horses are required to do the same amount of such work as plowing and disking per day as a two-plow tractor will do and that a three-plow tractor is equivalent to 9 or 10 horses on the same basis. In comparing the available power on Minnesota farms at different periods, it seems reasonable to consider the average tractor equivalent to 8 horses. The figures in the last column in Table 1 are computed on this basis. The total available drawbar horse power did not change much during this ten-year period altho there was a slight increase. If that portion of the present available truck and automobile power used for doing work that was formerly performed with horses were included, it could be shown that the present available drawbar power on the average Minnesota farm is much greater than it was ten years ago.

If each tractor is considered equivalent to 8 horses, the present available tractor power is about 55 per cent of the animal power. In 1921 the available tractor power was only about 16.5 per cent of the animal power.

[1] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262, p. 45. 1930.

[2] Hart, V. B. Farm Motor Trucks in New York. Cornell Agr. Expt. Sta. Bull. 427, p. 45. 1924.

The available power of a tractor at the belt is always greater than the drawbar power,[3] because a larger proportion of the power developed in the motor is lost through friction when it is transmitted to the drive wheels than when it is transmitted to the pulley. Another reason for this difference is that the tractor itself must always be moved before any drawbar power is available. The drawbar power ranges from 50 to 75 per cent of the belt power on most tractors.

For these reasons the farmer gets a relatively large amount of potential belt power as well as the drawbar power when he buys a tractor. The average tractor that is designed to pull two plows will develop about 20 horse power on the belt and the average three-plow tractor will develop about 30 horse power on the belt.[4] A conservative estimate based on the Nebraska tractor tests would place the belt power available on the average tractor at between 20 and 25 horse power. On the basis of 20 horse power per tractor, a total of 969,140 belt horse power was available from farm tractors in Minnesota in 1930. In 1921, 333,580 horse power was available. It is true that the tractor is replacing some stationary gasoline engines, but it is also true that electric motors are being acquired on many farms. Much of the farm belt work such as feed grinding, threshing, silo filling, etc., which was formerly done on a custom basis by large power units, is now being done by the farm tractor. In the main, however, only a small proportion of the available belt power on farms today is being utilized.

Automobiles and Trucks

The motor vehicle is becoming a very important factor in farm life and in the farm business. Cavert[5] shows that the automobile furnishes 30.9 per cent of the total power used for the farm business and for family use. No other source of power furnishes such a large proportion; horses furnish 29.7 per cent, tractors 23.3 per cent, and trucks 7.7 per cent.

Almost every farmer has an automobile and on many farms more than one are in use. The Federal Census[6] shows a total of 185,717 passenger cars on farms in the state in 1930. The automobile has released a large amount of animal power that was formerly used for road work, both pleasure and hauling. The trailer makes it possible to haul relatively large loads with the passenger car.

The Federal Census shows 36,557 motor trucks on farms in 1930.[7] There was one truck for every five farms in Minnesota in 1930. Motor

[3] Wallace, H. L. Nebraska Tractor Tests. Neb. Agr. Expt. Sta. Bull. 233. 1929.

[4] *Ibid.*

[5] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262, p. 11. 1930.

[6] Fifteen Federal Census. 1930.

[7] *Ibid.*

trucks for farm use are of two distinct types: the small runabout—frequently a remodeled passenger car—or a light truck that has been purchased secondhand. They are not used for heavy duty but for light hauling on the road and about the farm. Frequently they perform the function of a passenger car. On the other hand, the regular passenger car often performs the duties that ordinarily would fall on the light truck.

The type of truck in more general use on farms in the state is the one used for heavy hauling. This truck usually has a rated capacity of 1½ tons. Various types of bodies facilitate its use for a variety of purposes.

Cavert[8] found that 63 per cent of the trucks had a capacity of one ton or over; the remaining 37 per cent had a capacity of ¾ ton or less. The number of trucks in the state is increasing at a more rapid rate than the number of tractors. The percentage increase in tractors for 1920 to 1930 is 232; the trucks on farms increased from 3,803 to 36,557 or 861 per cent.

Electricity

The Federal Census for 1930 shows 23,342 farms supplied with electric energy.[9] No data are available showing what proportion of these are receiving high-line energy and what proportion have individual lighting plants. The number of farms receiving energy from central stations is increasing rapidly at present. White[10] states that 9.85 per cent of the number of farms in the United States in 1925 were receiving electric energy from a high line in 1930. This is an increase of 277 per cent in 6.5 years. Figure 3 shows the percentage of farms in each county that are using electricity.

From the standpoint of available farm power, the electric energy from high lines is much more significant than that from individual plants. It is true, however, that the individual plant makes possible a great many conveniences about the farmstead and in the farm home. Its primary function is to furnish light. Most plants have sufficient capacity to operate small appliances, such as the washing machine and the vacuum cleaner. Because high-line energy may be used for the operation of large motors to perform heavy belt work, it becomes a significant factor in the consideration of the total power supply on the farm.

The cost of such energy is rather high when used only for lighting and for operating one or two small motors. The rates for rural

[8] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262.

[9] Fifteenth Federal Census. 1930.

[10] White, E. A. Agriculture Turns On the Current. American Farming, vol. XXV, No. 12, p. 3. December, 1930.

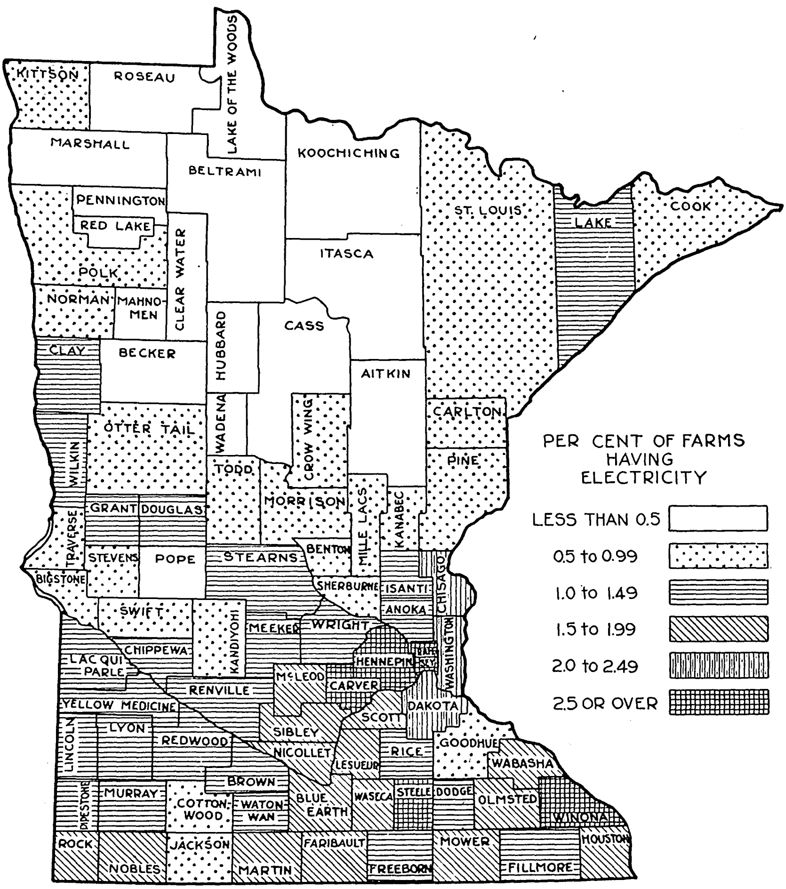

Fig. 3. Electricity on Minnesota Farms, 1929
The number of farms having electricity is relatively higher in the vicinity of St. Paul and Minneapolis and in some southern counties. Electricity from high lines is being introduced rapidly. The number of farms per mile is an important factor in the cost of obtaining electric energy and hence influence the rate at which farm connections in any community are made.

service are usually based on a sliding scale, which makes the cost per unit quantity relatively high for the first 40 to 60 kilowatt hours per month and considerably lower for all additional energy consumed. On farms where electricity is used for such belt work as grinding feed and filling silo, the total consumption per month usually is high enough to make the cost of energy for power purposes low in comparison with the cost of tractor power. An abundance of potential belt power becomes available on farms that are equipped with a tractor and that are receiving electricity from a central station.

A STUDY OF FARM TRACTORS IN MINNESOTA

Purpose of Study

The steadily increasing use of tractor power on Minnesota farms has introduced many problems of adjustment in the organization and operation of these farms. These problems are both engineering and economic. The tractor displaces a certain number of horses. To use the tractor effectively, new machinery adapted to tractor power must be added to the farm equipment. Both tractor and tractor equipment involve more mechanical ability on the part of the farmer than may be required for horse operation. The cropping system may need adjustment because of the lessened consumption of feed crops by horses and because certain crops and crop combinations lend themselves better to tractor tillage than do others. The tractor may reduce the amount of man labor required to operate the farm or make possible the operation of more acres or more intensive operation of the same acreage. The comparative cost of horse work and tractor work is of some importance as a factor affecting the adaptation of the tractor to the farm. Of even more importance is the effect of the tractor on the total income and on the total expense of farm operation.

Methods of Study

In order to learn the experience of farmers in fitting a tractor into their farm organization and to determine the items of cost involved in tractor operation, a survey was made in the spring of 1929 of 291 farms on which tractors were used. This survey was conducted cooperatively by the Divisions of Agricultural Engineering and Agricultural Economics of the Minnesota Experiment Station. Only farms on which a tractor had been in use at least one year were selected. The record included a description of the crop and livestock organization and the machine and farm equipment of these farms. A complete report of the cost of tractor operation for the year ending March 31, 1929, was obtained from each tractor operator. In addition, considerable supplementary information was obtained regarding the labor supply, the history of tractor use on the farm, the farming operations for which the tractor was used, and the farmers' opinion of the adaptation of a tractor to his farm. A sample of the survey blank used is to be found in the Appendix, pages 83-87.

DESCRIPTION OF FARMS STUDIED

Type of Farming

The location of the farms studied is shown in Figure 4. The farms are located about three centers, Owatonna in the southeast, Worthington in the southwest, and Crookston in the northwest. These three areas represent each of the three most important types

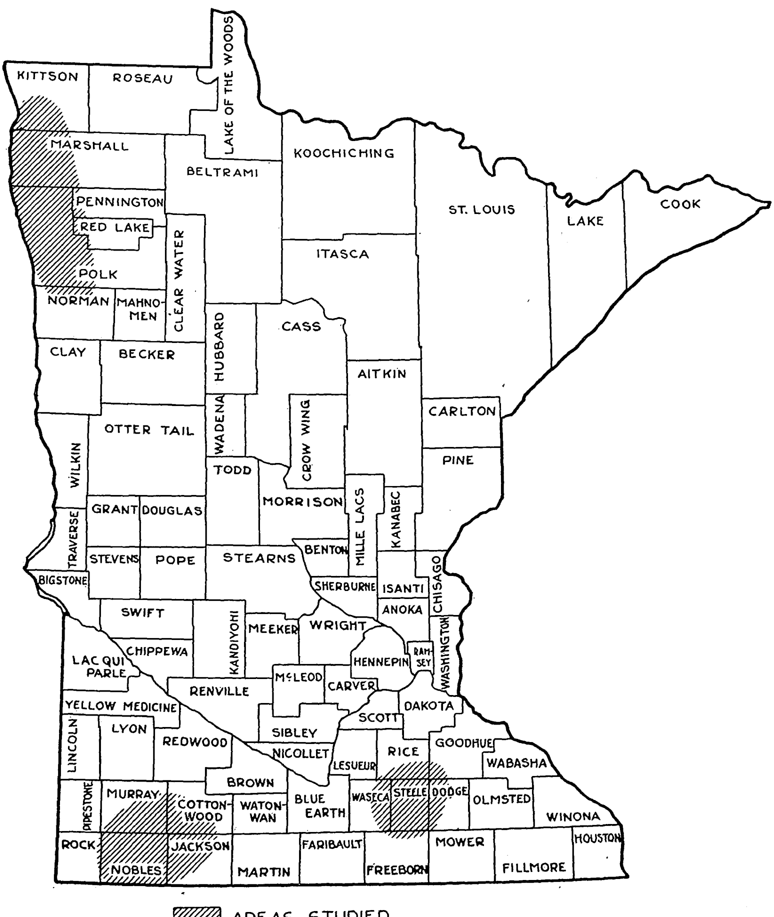

Fig. 4. Location of Areas in which Tractor Study Was Made

The areas selected for this study are representative of the three important types of farming in the state—dairying in the southeastern part, beef-cattle and hog raising in the southwestern part, and small-grain farming in the northwestern part.

of farming in the state. The farms in the vicinity of Owatonna are representative of the dairy type prevailing in the southeast and east central part of the state. The farms near Worthington are corn, beef-cattle and hog farms, of the type prevailing in that part of the state. In the Crookston area the farms are largely small grain farms of the type prevailing in the Red River Valley. Some livestock is maintained, but crops are the leading source of income. These three types furnish most of the problems of tractor adaptation that are to be encountered in the state.

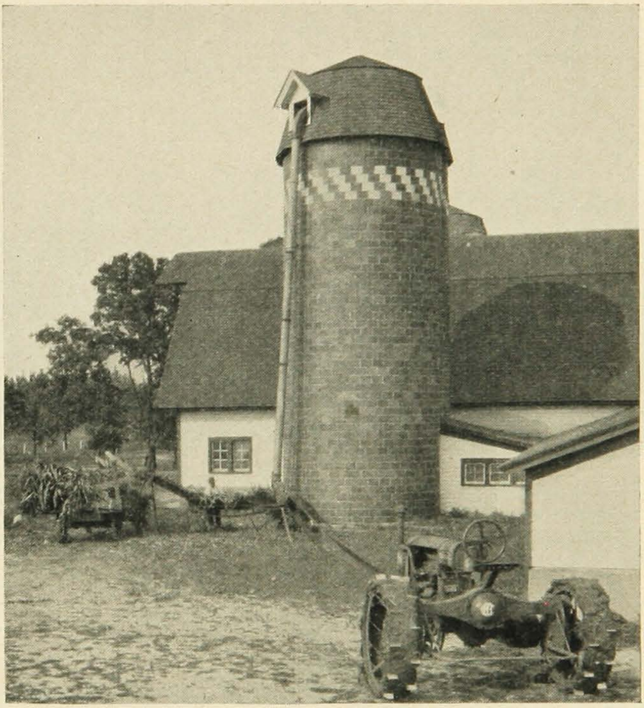

Fig. 5. A Tractor Supplying Power for Silo Filling
Silage is an important feed on dairy farms in southeastern Minnesota. More of the farmers interviewed in this section of the state used their tractors for silo filling than for any other kind of belt work.

Size of Farms

The number and size of farms studied are shown in Table 2. In each area the average size of the farms studied was much larger than the average for the counties in which they are located. As will be discussed later, the tractor can be used more effectively on the larger farm and most of the tractors in any locality will be found on farms of more than average size.

Table 2

Number and Size of Farms Studied and Comparisons with County Averages

	Southeast	Southwest	Northwest
No. of farms studied	105	86	100
Size of farms studied, acres			
Minimum	65	150	100
Maximum	470	1,033	2,000
Average	214	294	556
Average size of farms in counties where farms studied are located, acres	141	201	255

Fig. 6. A Tractor Operated Corn Picker

The use of mechanical corn pickers is increasing rapidly in southern Minnesota. The tractor has sufficient power not only to draw the corn picker and operate it with a power take-off but to haul the wagon in which the corn is collected. From 8 to 9 acres of corn can be picked in ten hours with a one-row picker and from 13 to 15 acres with a two-row picker.

Cropping Systems

Table 3

Average Acres of Crops Grown and Utilization of Land on Farms Studied

	Southeast	Southwest	Northwest
Small grain	67	111	327
Corn	45	99	15
Alfalfa	6	6	19
Other tame hay	15	12	26
Wild hay	10	6	20
Potatoes	..	1	10
Miscellaneous crops	3	1	8
Total acres harvested crops	146	236	425
Fallow and idle crop land	6	1	51
Rotation pasture	5	11	30
Permanent pasture (tillable)	17	16	12
Permanent pasture (not tillable)	29	17	18
Farmstead, waste, roads, and miscellaneous	11	13	20
Total acres in farm	214	294	556

The average acreage per farm of the crops grown on the farms studied, as well as the utilization of the land, is presented in Table 3. Small grain occupies 77 per cent of the crop area in northwestern

Minnesota but less than half in the other two districts. Cultivated crops, on the other hand, have an important place in the cropping systems in the latter two areas but are relatively unimportant in the Red River Valley. Ninety per cent or more of the land in the western two sections is tillable as compared with 81 per cent in the southeastern area.

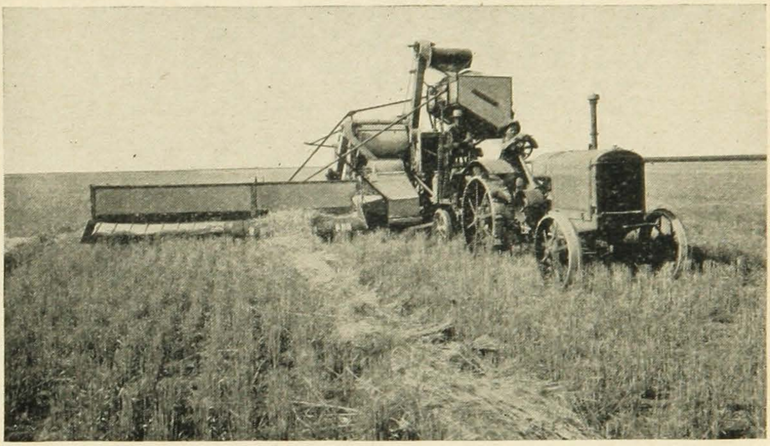

Fig. 7. Harvesting Grain with a Combine Harvester
The use of a combine harvester is increasing on the large farms of northwestern Minnesota. The windrower and the pick-up attachment, as shown, serve to adapt the combine to conditions. A two-plow tractor will furnish sufficient power for a ten-foot combine but a three-plow tractor is needed for the twelve- to sixteen-foot machines.

Livestock Systems

Table 4
Kind and Average Number of Head of Productive Livestock on Farms Studied

	Southeast	Southwest	Northwest
Dairy cows	15.6	5.9	8.9
Other dairy cattle	13.0	7.5	7.4
Beef cows	1.0	7.4	1.5
Other beef cattle	1.3	10.6	1.2
Hogs	8.6	13.3	4.3
Sheep	3.1	13.9	26.4
Poultry	172	170	108
Total animal units*	27.6	28.7	20.4
Animal units per 100 acres	12.9	9.8	3.7
Animal units per 100 crop acres	18.9	12.2	4.8

* The following numbers of livestock are considered one animal unit: 1 cow, 2 young cattle, 5 hogs, 10 pigs, 7 sheep, 14 lambs, 100 chickens.

The kind and amount of livestock on the farms studied is shown in Table 4. The farms studied in the southern part of the state are livestock farms. In southeastern Minnesota dairy cattle are the most important livestock, with hogs ranking second. Beef cattle predominate in southwestern Minnesota, with hogs following closely as a source of income. About 90 per cent of the cash income is derived from the sales of livestock and livestock products on the dairy farms and approximately 80 per cent on the beef cattle and hog farms. The sales of livestock and livestock products furnish less than half of the total cash income on the small-grain farms of northwestern Minnesota.

POWER SUPPLY ON FARMS STUDIED

Tractors

A total of 314 tractors is included in this study: 105 in southeastern, 87 in the southwestern, and 122 in the northwestern part of the state.

None of the farmers interviewed in southeastern Minnesota had more than one tractor, in southwestern Minnesota one farmer had two tractors, and in northwestern Minnesota 15 per cent of the operators had more than one tractor.

No consistent relationship seems to exist between the size of farm and the size of tractor used. Table 5 shows a smaller percentage of two-plow tractors in the northwest where the farms are larger. On the other hand, the relationship between the two-plow and three-plow tractors is about the same in the other two sections of the state with a decided difference in the size of farms in the two areas. Apparently the type of farming is an important factor in determining the size of the tractor. In northwestern Minnesota the combination of large fields and relatively large farms encourages the use of large implements and thus creates the need for a large power unit to pull them.

Table 5

Size of Farms, Size of Fields, and Number and Size of Tractors

	Southeast	Southwest	Northwest	All areas
Average size of farms, acres	214	294	556	355
Average size of fields, acres	14	22	37	24
Number of tractors	105	87	122	314
Two-plow tractors, per cent	49	54	28	42
Three-plow tractors, per cent	48	45	65	54
Tractors larger than three-plow, per cent	3	1	7	4

Most of the tractors studied were the standard wheel type. Seven of the 314 were general purpose tractors. Five of these were found in the southwest and one in each of the other two areas. Only one was of the track-laying type.

Table 6 gives the age distribution of all tractors included in the study. Over half were less than four years old. There seems to be an abrupt drop in the number of tractors about five years old but little change after that. This indicates that many tractors are disposed of at about that age. The figures in the table also indicate that most of the tractors that are not disposed of then are used for another five years or longer. In this connection it should be noted that some marked improvements in tractors were made about five years before the survey was taken. It is probable that many tractors were exchanged for new ones about that time, and that obsolescence was an important factor influencing this condition.

Table 6

Age of Tractors Studied

Years	Tractors of different ages, per cent			
	Southeast	Southwest	Northwest	All areas
2 or less	31	36	40	36
3 and 4	28	31	31	30
5 and 6	11	15	8	11
7 and 8	11	6	3	6
9 and 10	16	6	10	11
Over 10	3	6	8	6

Seventy-nine per cent of all of the tractors were purchased new. In northwestern Minnesota the tendency to buy used tractors seems to be more marked than in the other two areas. Here only 73 per cent were purchased new. In southwestern Minnesota 81 per cent were purchased new, and in southeastern Minnesota 85 per cent. The average age of all second-hand tractors at time of purchase by the present owners was 4.6 years.

Horses

The number of work horses per farm is shown in Table 7. The tractor and horses together constitute the available drawbar power. Altho these two forms of power are quite different in many respects they have some characteristics in common. It is desirable to make a comparison of the two for purposes of determining the total available drawbar power on farms that have both tractor and horses. As will be shown later, the useful available power of a two-plow tractor for such ordinary heavy field work as plowing and disking is approximately equivalent to that of 7 horses; the three-plow tractor will do an amount of work that would require about 10 horses. It is assumed that the average horse will develop one horse power. With these units as a basis of comparison, the total drawbar power per farm is shown in Table 7, computed. The average for all farms in the study is 16.2 horse power, and the average number of horses per farm is 7.3. The tractor drawbar power per farm is about the same in all areas.

The number of horses per farm bears a relation to the size of farm but is not in direct proportion, so the smaller farms have a relatively larger quantity of power than the larger ones. This is shown by the number of acres per drawbar horse power (Table 7). These figures indicate a higher efficiency in the use of drawbar power on the larger farms than on the smaller ones. It must be remembered, however, that because of the more intensive type of livestock farming in these areas, a larger number of horse power hours are required per acre in southeastern and southwestern Minnesota than in the northwest. A certain amount of belt work is also necessary on livestock farms. It is questionable, on the other hand, if these factors are of sufficient importance to justify all of the difference in the available power per acre in the different areas. Doubtless, the difference in farm size is an important factor.

Table 7

Total Drawbar Power per Farm on Farms Studied

	Southeast	Southwest	Northwest	All areas
Acres per farm	214.0	294.0	556.0	355.0
Work horses per farm	6.0	7.0	8.6	7.3
Tractor drawbar power per farm, horse power	8.6	8.4	9.6	8.9
Total drawbar power per farm, horse power	14.6	15.4	18.2	16.2
Acres per drawbar horse power	14.7	19.1	29.9	21.9

The larger farm allows a more extensive use of the tractor than the smaller one. Table 13 indicates that farmers in northwestern Minnesota are somewhat more inclined to use the tractor for operations that have usually been considered as horse work. Seeding grain and operating the binder are two examples. A larger percentage of them also use the tractor for harrowing. These facts suggest that farmers in southern Minnesota might do well to consider the possibility of performing a larger number of operations with the tractor, thus making it possible to dispose of more horses and reducing the total power cost on the farm.

Trucks and Automobiles

Some information with regard to the number of automobiles and trucks on the farms studied is given in Table 8. Almost every farm has either a truck or a passenger car or both. Trucks are found on a third of the farms. Trucks are less numerous in the southwestern district than in the other two locations. Most of these farmers have only one passenger car, but it is interesting to note that 22 per cent have two passenger cars and 3 per cent have more than two. In many cases the family automobile is used for light hauling as well as for pleasure.

Numerous makes of automobiles are represented. By far the larger proportion is cars that sell for less than $1,000. Thirty-three per cent of the cars were two years old or less when the survey was made; 41 per cent were five years old or less.

Table 8

Trucks and Automobiles on Farms Studied

	South-east	South-west	North-west	All	Per cent of total
Farms without automobile or truck ...	0	0	2	2	1
Farms with truck	42	14	39	95	33
Farms with one automobile	72	62	79	213	73
Farms with two automobiles	31	20	12	63	22
Farms with three or more automobiles	1	3	4	8	3

Stationary Gasoline Engines and Electric Motors

The number of farms that are equipped with gasoline engines and those that have electric motors are shown in Table 9. The number of farms having one, two, or more of each of the two forms of power is also given. Over 50 per cent of the farms studied have one gasoline engine and 18.2 per cent have two. There is at least one gasoline engine on 74 per cent of the farms.

Electric motors are not so numerous as gasoline engines. A larger percentage of farms on which electric power is used, however, have two, three, or more motors. One of the desirable characteristics of electric power is that it may be had in relatively small units. It is readily distributed to almost any point on the farmstead or any farm building. It is not necessary to group all of the appliances to be operated with electric power around one line shaft operated by an individual power unit. Electric motors are obtainable in numerous sizes and the cost of getting work done is not increased appreciably by having a relatively large number of small units.

Table 9

Number of Farms Having Stationary Gasoline Engines and Electric Motors

	Number of farms						Percentage of farms	
	Southeast		Southwest		Northwest		All areas	
Number of units	Gasoline engines	Electric motors	Gasoline engines	Electric motors	Gasoline engines	Electric motors	Gasoline engines	Electric motors
1	55	8	46	5	49	6	51.5	6.5
2	16	16	22	13	15	1	18.2	10.3
3	3	19	0	0	5	7	2.7	9.0
4	1	5	0	0	3	1	1.4	2.0
5	0	2	0	0	1	1	0.4	1.0
6	0	1	0	0	0	0	0.0	0.4
Total	75	51	68	18	73	16	74.2	29.2

Electric power was found on 29.2 per cent of the farms visited. Electric energy from central stations is being made available to farms at a rapid rate, and it is likely that this percentage will be increased considerably in the near future.

Table 10 shows the operations that are performed by gasoline engines and by electric power; also the number of farms reporting each operation. It is evident that these two forms of power are direct competitors. As will be shown in Table 13, the tractor is used for such operations as filling the silo, grinding feed, shelling corn, and sawing wood. The stationary gasoline engine doubtless was used to furnish power for such work on many farms before the tractor was used. It would be practical to use the tractor for some of the operations, such as shelling corn and sawing wood, that are now being performed by the stationary gasoline engine and the electric motor. In the main, however, there is not much possibility of profitably increasing the tractor work by the operations for which the smaller power units are now used.

Table 10

Operations for Which Stationary Gasoline Engines and Electric Motors Are Used and Number of Farms Reporting Each Operation

Operation	Number of farms						Percentage of farms	
	Southeast		Southwest		Northwest		All areas	
	Gasoline engines	Electric motors	Gasoline engines	Electric motors	Gasoline engines	Electric motors	Gasoline engines	Electric motors
Pumping	45	30	49	8	41	10	46.5	16.5
Washing	14	35	24	13	22	9	20.6	19.6
Separating cream	13	34	4	7	5	4	7.6	15.5
Grain cleaning	11	8	5	2	45	3	21.0	4.5
Feed grinding	3	5	0	1	13	0	5.5	2.1
Sharpening tools	1	5	1	3	2	0	1.4	2.7
Milking	15	23	2	2	1	4	6.2	10.0
Sawing wood	7	2	3	0	6	1	5.5	1.0
Elevating grain	10	3	4	1	21	1	12.0	1.7
Shelling corn	2	0	6	1	0	0	2.7	0.3
Generating electricity	3	..	3	..	1	..	2.4	..

The electric motor is relatively new in comparison with the gasoline engine. It is rapidly replacing it for such machines as the milking machine, the cream separator, the washing machine, and the pump. Doubtless one important reason why the gasoline engine is used for pumping water on more than 46 per cent of the farms is because it was used for that purpose before electricity became available, and the present resale value of a gasoline engine is very small. Many of them probably will be replaced with electric motors after they are worn out.

The gasoline engine is still in greater demand than the electric motor for such work as sawing wood and elevating grain, probably because it may be moved about freely without any consideration of the accessibility of the source of energy.

One important reason for replacing the stationary gasoline engine with the electric motor for many operations is to build up the load and thus to decrease the cost per unit quantity of energy. As the stationary gasoline engine furnishes only belt power, the electric motor will usually replace it entirely, thus eliminating the overhead cost. It is highly desirable to do as much work as possible with electric energy where it is obtained from a central station because the cost per unit quantity consumed decreases as the consumption increases.

WORK DONE BY TRACTORS

Hours of Use Annually

The range in number of hours of use annually per tractor is shown in Table 11. A wide variation in the number of hours a tractor is used annually occurs among different farms and different localities. In general the larger the farm the more work there is for the tractor to do. Some farmers secure a fuller utilization of their tractor by doing custom work. The extent to which custom work is done and the receipts per farm from this source are shown in Table 12.

The data show that the tractors on the farms of smallest size are used least for custom work. There are more tractors per 1,000 acres of land in crops in southeastern Minnesota and hence less work per tractor. Then, too, these farms are heavily stocked and the operator is less able to get away from the home farm than if he had no livestock demanding frequent and regular attention. Most of the custom work is belt work. The farmer without a tractor does his field work with horses but hires his neighbor's tractor for belt operations.

Table 11

Range in Hours of Use Annually per Tractor

Group	Number of tractors in group			
	South ast	Southwest	Northwest	All areas
Hours				
Under 100	2	5	4	11
100-199	22	11	13	46
200-299	32	13	15	60
300-399	26	23	18	67
400-499	8	10	14	32
500-599	11	9	19	39
600-699	1	9	13	23
700-799	2	3	8	13
800-899	0	2	3	5
900-999	1	1	5	7
1,000 and over	0	1	10	11
	Hours of tractor use annually			
Maximum	939	1,020	2,615	2,615
Minimum	30	80	50	30
Average	311	398	522	417

Table 12

Custom Work Done with Tractors on Farms Studied

	South-east	South-west	North-west	All areas
Percentage of farms reporting custom drawbar work	21	24	28	24
Percentage of farms reporting custom belt work	45	50	56	50
Percentage of farms reporting custom work with tractor (all work)	49	58	66	57
Percentage of total drawbar work that is custom work	3	8	4	5
Percentage of total belt work that is custom work	24	67	49	47
Percentage of all tractor work that is custom work	11	23	14	16
Average receipts per farm for custom drawbar work for farms reporting*	$52	$160	$177	$133
Average receipts per farm for custom belt work for farms reporting*	156	631	419	397
Average receipts per farm for all custom work*	166	610	426	404

* The receipts for custom work include a wage for any labor furnished with the tractor and a rent for any machinery furnished by the tractor owner, as well as a payment for the tractor power itself.

Operations for Which Tractors Are Used

The operations for which tractors are used are shown in Table 13, together with the number of farms on which the tractors are used for each of the operations listed and the average number of hours of such work per farm. Plowing is by far the most important drawbar operation, constituting 62 per cent of all drawbar work. Other operations of seedbed preparation make up an additional 23 per cent. A few farmers used tractors for seeding small grain and cultivating corn. Harvesting operations make up 11 per cent of the drawbar work and 2 per cent of the miscellaneous work. The miscellaneous work includes mowing, raking, and hauling hay; hauling bundles; hauling manure; planting, spraying, cultivating, and digging potatoes; ditching; excavating; and similar operations.

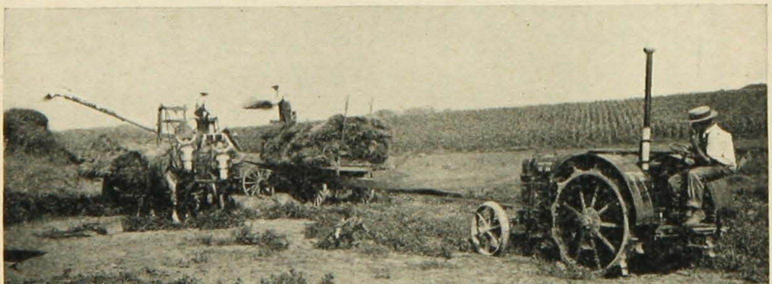

Fig. 8. Threshing Grain with Tractor Power

Threshing was 56 per cent of all belt work done on the farms studied. Small outfits like this can be operated with a comparatively small crew and make it possible for the farmer to do his threshing when most convenient. Outside custom threshing may be an additional source of income for the tractor-owning farmer.

Table 13

Operations for Which Tractors Were Used, Number of Farms Reporting Each Operation, and Average Hours Annually for Farms Reporting

Operations	Southeast		Southwest		Northwest		All areas	
	Per-cent-age of farms	Hours per farm	Per-cent-age of farms	Hours per farm	Per-cent-age of farms	Hours per farm	Per-cent-age of farms	Hours per farm
Drawbar work								
Plowing	98	130	95	164	99	319	99	205
Disking	46	38	Co	81	54	74	54	66
Spring-tooth harrowing	84	50	24	33	46	94	54	60
Harrowing	13	.15	29	26	34	35	25	28
Seeding	..	..	..	..	15	85	5	85
Harv sting, binder	17	34	41	48	50	84	36	63
Harvesting, windrower and combine	..	..	..	..	7	262	2	262
Cultivating corn	..	..	5	166	..	..	2	166
Picking corn	5	54	24	95	..	..	9	87
Miscellaneous	25	11	13	19	29	60	23	33
Total drawbar work, average	98	206	100	287	100	506	99	346
Total drawbar work, maximum	..	538	..	885	..	2,340	..	2,340
Total drawbar work, minimum	..	0	..	25	..	0	..	0
Belt work								
Threshing	33	67	44	145	53	180	44	138
Silo filling	74	27	20	31	20	26	40	28
Corn shredding	45	46	2	21	1	10	17	44
Feed grinding	74	54	43	31	55	59	59	50
Wood sawing	39	11	26	22	19	13	29	15
Corn shelling	..	..	26	61	..	..	8	61
Miscellaneous	2	205	3	4	1	10	2	72
Total belt work, average	98	113	76	144	80	169	85	127
Total belt work, maximum	..	450	..	470	..	568	..	568
Total belt work, minimum	..	0	..	0	..	0	..	0
Total tractor work, average	100	311	100	380	100	637	100	450
Total tractor work, maximum	..	793	..	1,385	..	2,615	..	2,615
Total tractor work, minimum	..	30	..	80	..	59	..	30

Half of all belt work done by these tractors was threshing, but the importance of this operation varies in different parts of the state. Only 20 per cent of the belt work in southeastern Minnesota was threshing, 60 per cent in the southwestern part of the state, and 70 per cent in the northwestern part. Twenty-five per cent of all belt work was feed grinding, but this varied from 39 per cent of the total in the southeastern section to 13 per cent in the southwestern. Silo filling and corn shredding were important operations in the southeastern section but of little importance elsewhere. Corn shelling was second in importance to threshing in southwestern Minnesota.

Rate of Performance

The average rate at which these tractors performed the operations for which they were commonly used is shown in Table 14. Averages for both 2-plow and 3-plow tractors are given. Rates are shown for the various sizes of implements most commonly used. There was considerable variation between different farms in the rate at which this work was done. Size of farm, condition of soil, yield of crops, and similar factors were responsible for this variation. The usual rate of travel for the heavier operations, such as plowing, disking, and spring-tooth harrowing was 2½ miles per hour. For lighter work, as harrowing or windrowing, the tractor often was speeded up considerably beyond this rate. No information is available as to whether the corn cultivation reported includes the first cultivation or only later cultivations. It is hardly likely that corn could be cultivated at this rate the first time over, but a slower first cultivation may be offset by speeding up the tractor for the later cultivations.

Table 14

Average Acres Covered per Hour by 2-Plow and 3-Plow Tractors for Different Operations and with Different Sizes of Implements

Operation	Size of implement	Acres per hour	
		2-plow tractor	3-plow tractor
Plowing	2 14-inch bottoms	0.7	..
	3 14-inch bottoms	..	1.0
Disking	8-foot disk	2.4	3.0
	10-foot disk	2.8	3.5
Spring-tooth harrowing	8-foot spring-tooth harrow	2.1	..
	10-foot spring-tooth harrow	2.6	2.9
	12-foot spring-tooth harrow	..	3.4
Harrowing	20-foot spike-tooth harrow	6.1	6.7
	26-foot spike-tooth harrow	7.9	8.8
Seeding	10-foot drill	2.8	...
	12-foot drill	..	4.0
Harvesting	7-foot binder	2.1	2.2
	8-foot binder	2.4	2.5
	10-foot binder	3.0	3.1
	2 8 foot binders	..	4.2
	12-foot windrower*	3.8	..
	16-foot windrower	5.0	..
	8-foot combine* (power take-off)	..	2.1
	10-foot combine (auxiliary engine)	2.5	..
	12-foot combine (auxiliary engine)	..	3.1
	16-foot combine (auxiliary engine)	..	4.0
Cultivating corn	2-row cultivator	2.0	..
Picking corn	1-row picker	0.8	0.9
	2-row picker	1.3	1.5

* Data for windrower and combine taken from Minn. Agr. Expt. Sta. Bull. 266. Too few windrowers and combines were used on the tractor farms surveyed to form an adequate basis for a rate for these operations.

No rate of performance of belt operations is given. The machines used as well as the conditions under which they were operated varied so widely that an average rate would have little significance. Some of the belt work, such as threshing and silo filling, was done during the rush of the crop season; other work, such as feed grinding and wood-sawing, was done largely during slack periods, especially in winter. As a result the tractor is not likely to be run at nearly as uniform a share of its capacity in doing belt work as in drawbar work.

FACTORS OF TRACTOR COST

The survey upon which this study is based covered 291 farms on which 314 tractors were used. Some of these were tractors of an obsolete type and used only occasionally and for special operations. In order to eliminate these, no tractors used less than 100 hours per year are included in this discussion of tractor cost. Ninety-six per cent of the tractors on the farms studied are of the size usually classed as either "two-plow" or "three-plow." As there are too few of the larger sizes to furnish an adequate basis for determining costs, all sizes larger than the three-plow tractor have been omitted. In a few cases the cost items for tractors of different sizes on the same farm were combined in such a way as to make impossible an accurate separation. In other cases obvious discrepancies in the data have made it

Fig. 9. Grinding Feed with Tractor Power

More of the tractors studied were used for grinding feed than for any other belt operation. The steady increase of livestock makes an increasing demand for ground feed. The tractor owner may save time and expense by grinding his own feed and may also derive some additional revenue from custom work.

necessary to discard certain records. In the following discussion of factors of cost, the data covering 121 two-plow tractors and 142 three-plow tractors are used. Forty-four of the two-plow tractors were models currently manufactured at the time of the survey and 77 were models that had been discontinued by the manufacturer. Of the three-plow tractors, 78 were current models and 64 were obsolete. As there was no significant difference in factors of cost between the current and obsolete models except that resulting from age, the two models have been combined in studying the cost factors. The data from the three different sections of the state have also been combined in most of the cost discussion, as type of farming affects unit cost of tractor operation largely through the amount of tractor work available and the nature of the operations to be performed. These points will be given separate consideration later.

Fuel and Oil

Forty-nine per cent of the fuel used in the tractors studied was gasoline, 44 per cent was kerosene and 7 per cent was distillate. Thirty-nine per cent of the operators used gasoline exclusively, 10 per cent used about equal quantities of gasoline and kerosene, and the rest used gasoline only for starting. The last group used one gallon of gasoline to approximately 25 gallons of kerosene or distillate. The average fuel consumption per hour of the two-plow tractors was 1.92 gallons and of the three-plow, 2.54 gallons. There was no difference in the fuel consumption per hour between the tractors using gasoline exclusively and those using kerosene or distillate. The price paid for gasoline ranged from 13 cents to 20 cents per gallon; of kerosene from 11 cents to 16 cents, and of distillate from 8 cents to 9 cents. The average prices paid were 16½ cents for gasoline, 13½ cents for kerosene, and 8½ cents for distillate. The average price of all fuel was 15 cents per gallon. In order to eliminate differences in cost of tractor operation due to differences in the price paid for fuel, the costs of operating each tractor have been computed on the basis of the average price of fuel for all tractors.

The average consumption of cylinder oil was 0.09 gallons per hour for the two-plow tractors and 0.12 gallons per hour for the three-plow tractors. The average price paid for cylinder oil was 70 cents per gallon. This price has been used in computing the cost of oil for all tractors. The average expenditure for other oils and greases was one cent per hour for both two-plow and three-plow tractors.

Repairs

The annual cost of repairs varied widely. Some of the causes for variations will be discussed later. The average cash expenditure for repairs per hour of operation for both the two-plow and three-plow tractors was 6 cents. This includes both the purchase of parts and any expert labor hired to repair or overhaul the tractor. In addition to this cash expense for repairs, the farmer spends some time daily in servicing his tractor and in many cases does all or part of the repairing and overhauling. The average time so spent was 0.11 hours of man labor per hour. In other words, the operators spent one hour in servicing and repairing the tractor for every nine hours of tractor operation. This labor is charged at the rate of 30 cents per hour, the average rate paid hired men on the farms studied.

Depreciation and Interest

The annual depreciation charge is based on two factors, the purchase price and the estimated working life. The average purchase price of the two-plow tractors included in this study was $776. The price varied from $430 to $1,300. The average purchase price of tractors of a type discontinued before this study was made was $718 and of current models $973. The large percentage of Fordsons in the group of obsolete models accounts for the low purchase price in that group. Other obsolete models were higher in price than the current models of the same rating. The average purchase price of the three-plow tractors was $1,335; the range was from $800 to $2,400. The average price was $1,419 for the obsolete models and $1,265 for the current models. Seventy-nine per cent of the tractors studied were purchased as new machines by the present operators. In order to put all machines on a comparable basis, the purchase price used in computing the averages just quoted was the original price of the machine and not the price paid for the used machine by the present operator.

The wide variation in price is due to several factors. Tractors of the same rating are priced differently by different manufacturers. The price of the same make and model varies among different dealers and even for the same dealer with different purchasers. Seventy per cent of the tractors studied were bought for cash (including trade-ins) and 30 per cent were bought on time. The usual time allowed was 18 months. A discount of from 7 to 8 per cent for cash was commonly reported. Another important factor accounting for the variation in purchase prices is the year in which the tractor was purchased. The machines studied were purchased over a period ranging from 1916 to 1928. Tractor prices have fluctuated widely during this period.

The age of the tractors varied from one to 13 years. The average age of the two-plow tractors was 4.6 years and of the three-plow, 4.8 years. Each operator was asked to estimate the probable life of his tractor. More than half had had previous tractors and some had been using them for 20 years. The average time of tractor experience per operator was 8 years. Their estimates of probable life, based on their experience and judgment, varied widely but the average was 11 years. This average includes some tractors used only for belt work and then only for a comparatively few hours a year. For the tractors in general use, the average was approximately 10 years. Estimates of the probable life of tractors adjusted according to hours of use have been deduced from the answers received from the operators and are presented in Table 15. The annual depreciation charge is obtained by dividing the purchase price of the tractor by the years of service, indicated by the annual hours of use.

Table 15

Probable Life of Tractors Adjusted According to Annual Hours of Use

Annual use, hours	Estimated life, years
Under 200	12
200-349	11
350-499	10
500-699	9
700-999	8
1,000 and over	7

Interest has been charged at 8 per cent on the average investment in the tractor.[11] This was the prevailing rate on unpaid balances on tractors bought on time.

Miscellaneous Cost Items

In addition to the costs already discussed, there are a number of minor cost items that have not been included in this study. These include shelter charges, taxes, and insurance. Many of the tractors studied were not sheltered and for those that were housed the cost was minor. No adequate basis for an allocation of taxes and insurance to the tractor was available. As at most these charges would amount to only a few cents per hour of operation, they have been omitted.

SUMMARY AND ANALYSIS OF COSTS

Average Cost per Hour of Tractor Operation

The average cost per hour of operating both 2-plow and 3-plow tractors included in this study is shown in Table 16. The comparison between the average costs for the two sizes may be somewhat misleading, as the larger tractors were used more hours per year and hence have relatively lower fixed charges per hour. If both sets of cost figures are adjusted to the average annual use for the two groups, 437 hours, the costs per hour would be 71 cents and $1.00, respectively. It has been noted that the purchase price of current models of 2-plow tractors is higher than the average price used and that of the 3-plow tractors lower. If the costs are computed on the basis of the purchase price of current models and the same number of hours of use annually as in the previous comparison, the costs would be 74 cents and 98 cents, respectively.

The items of tractor cost have been divided into two classes for the purpose of this study. The first group is operating costs. It includes the cost elements—fuel, lubricants, and repairs—which vary

[11] The average investment was determined according to the formula: Average annual

$$\text{investment} = \frac{\text{first cost} \times (\text{years of service} + 1)}{\text{years of service} \times 2}.$$

more or less directly with the use of the tractor. With the exception of the charge for repairing and servicing done by the farmer or members of his family, the operating costs represent direct cash outlay. The other group is called fixed charges. They are computed on an annual basis and the charge per hour varies widely with the annual hours of use. Altho the annual depreciation is modified according to the use, it is by no means directly proportional to the use. The interest charge is entirely on an annual basis. These fixed charges also differ from operating costs in that they do not represent current cash expenditure. Still the purchase price of the tractor and the interest charge, at least interest on a tractor note, are in the long run just as real items of cost as are the current expenditures for fuel and oil. The relative importance of these two classes of costs for any particular tractor varies with the number of hours of annual use. The more hours a tractor is used per year the greater will be the share of operating costs of the total cost per hour.

Table 16

Average Cost per Hour of Tractor Operation

	2-plow tractors			3-plow tractors		
Base Data						
Purchase price	$776			$1,335		
Estimated life, years	10			10		
Hours worked annually	396			478		
Fuel, gallons	1.92			2.54		
Cylinder oil, gallons	0.09			0.12		
Man labor, hours	0.11			0.11		
Calculated Costs						
Operating costs:						
Fuel at 15 cents per gallon		$0.29			$0.38	
Cylinder oil at 70 cents per gallon	$0.06			$0.08		
Other oils and greases	0.01			0.01		
Total lubricants		0.07			0.09	
Cash repairs	0.06			0.06		
Labor at 30 cents per hour	0.03			0.03		
Total repairs and servicing		0.09			0.09	
Total operating costs			$0.45			$0.56
Fixed charges:						
Depreciation (10-year life)		0.20			0.28	
Interest at 8 per cent		0.09			0.12	
Total fixed charges			0.29			0.40
Total costs per hour			$0.74			$0.96

Tractor Costs for Specific Farm Operations

Fuel is the only item of tractor cost that varied materially on an hour basis, according to the nature of the work. Certain operations and certain implements require much more power than others. The variation in fuel consumption for both 2-plow and 3-plow tractors is shown in Table 17 for different operations and different sizes of implements.

The figures on fuel consumption give a rough measure of the relative power demands of different operations. The tractor is used most nearly to capacity at such operations as plowing, disking, and spring-tooth harrowing but such implements as the spike-tooth harrow and the grain binder utilize only part of the tractor's power capacity.

Table 17

Average Hourly Fuel Consumption of Tractors for Different Drawbar Operations and with Different Sizes of Implements

Operation	Size and kind of implement	2-plow tractors	2-plow tractors
		gal.	gal.
Plowing	2 14-inch bottoms	2.05	...
	3 14-inch bottoms	...	2.64
Disking	8-foot disk	1.90	2.25
	10-foot disk	2.18	2.61
Spring-tooth harrowing	8-foot spring-tooth harrow	1.95	...
	10-foot spring-tooth harrow	2.24	2.26
	12-foot spring-tooth harrow	...	2.60
Harrowing	20-foot spike-tooth harrow	1.76	2.22
	26-foot spike-tooth harrow	1.83	2.36
Seeding	10-foot drill	1.63	...
	12-foot drill	...	2.54
Harvesting	7-foot binder	1.54	2.10
	8-foot binder	1.64	2.20
	10-foot binder	1.85	2.42
	2 8-foot binders	...	2.71
	12-foot windrower	1.55	...
	26-foot windrower	1.64	...
	8-foot combine with power take-off	...	2.51
	10-foot combine with auxiliary engine	2.10	...
	12-foot combine with auxiliary engine	...	2.60
	16-foot combine with auxiliary engine	...	3.10
Cultivating corn	2-row cultivator	1.50	...
Picking corn	1-row picker	1.70	2.07
	2-row picker	2.03	2.50

The cost of tractor power per acre for different drawbar operations with implements of different sizes is shown in Table 18. These costs are computed from the data presented in Tables 14, 16, and 17. The fuel cost per hour is computed from Table 17. All costs except fuel are taken from Table 16. The sum of these two items is divided by the acres per hour as shown in Table 14 in order to get the cost per acre. One significant fact brought out in this table is that there is little difference in tractor cost per acre between two- and three-plow tractors at operations such as plowing, disking, and spring-tooth harrowing where both sizes are used approximately at full capacity. On the other hand, the larger tractor is at a disadvantage in case of such operations as harrowing and cutting grain with a binder. For these operations, the smaller tractor is used more nearly to its optimum capacity than the larger one. It is also apparent from these data that the larger the implement pulled by a tractor of a given size, provided, of course, that the draft of the implement does not exceed the capacity of the tractor, the lower will be the cost per acre. The utilization of the full capacity of a tractor is an important factor in its economical operation, as will be discussed later.

Table 18

Average Tractor Cost per Acre of Different Drawbar Operations with Different Sizes of Implements

Operation	Size and kind of implement	2-plow tractors	3-plow tractors
Plowing	2 14-inch bottoms	$1.09	...
	3 14-inch bottoms	...	$0.98
Disking	8-foot disk	0.31	0.31
	10-foot disk	0.28	0.28
Spring-tooth harrowing	8-foot spring-tooth harrow	0.35	...
	10-foot spring-tooth harrow	0.30	0.32
	12-foot spring-tooth harrow	...	0.29
Harrowing	20-foot spike-tooth harrow	0.12	0.14
	26-foot spike-tooth harrow	0.09	0.11
Seeding	10-foot drill	0.25	...
	12-foot drill	...	0.24
Harvesting	7-foot binder	0.32	0.41
	8-foot binder	0.29	0.36
	10-foot binder	0.24	0.30
	2 8-foot binders	...	0.24
	12-foot windrower	0.18	...
	16-foot windrower	0.14	...
	8-foot combine with power take-off	...	0.46
	10-foot combine with auxiliary engine	0.31	...
	12-foot combine with auxiliary engine	...	0.31
	16-foot combine with auxiliary engine	...	0.26
Cultivating corn	2-row cultivator	0.34	...
Picking corn	1-row picker	0.89	0.99
	2-row picker	0.58	0.64

The fuel consumption per hour as well as the total tractor cost per hour for the common belt operations is shown in Table 19. All costs other than fuel are taken directly from Table 16. To these have been added the cost of the quantity of fuel shown in this table at the average price paid, 15 cents per gallon, and the sum is the total tractor cost per hour. The fuel consumption data give some indication of the relative extent to which the use of the tractor at different belt operations approaches the full utilization of its capacity. They do not, however, indicate this as accurately as do the data for the drawbar operations, as information concerning the size of implement as well as the rate of output are lacking. Still it is apparent that threshing requires considerably more power than the other belt operations. No comparison between the relative economy of two-plow and three-plow tractors for the same operation is possible, as no rate of output is given.

Table 19

Fuel Consumption and Total Tractor Costs per Hour for Belt Operations

Operation	Gallons fuel per hour		Total cost per hour	
	2-plow	3-plow	2-plow	3-plow
Threshing	2.25	2.83	$0.79	$1.00
Filling silo	1.96	2.38	0.74	0.94
Grinding feed	1.78	2.02	0.72	0.88
Shelling corn	1.70	1.80	0.71	0.85
Shredding corn	1.58	1.92	0.69	0.87
Sawing wood	1.56	2.00	0.68	0.88

Factors Influencing Cost

This study brought out a wide range in the cost per hour of tractor operation among different farms. The cost of 2-plow tractors ranged from 40 cents to $1.96 per hour and of 3-plow tractors from 56 cents to $3.56 per hour. One of the factors causing this variation is the kind of work for which the tractor is used. This has already been considered under the discussion of the cost of performing specific operations. In general, the more nearly to capacity the tractor is used the higher is the cost per hour. On the other hand, the cost per unit of work performed is usually less when the potential power of the tractor is being fully utilized.

One of the most important factors affecting the cost per hour of tractor work is the number of hours that the tractor is used annually. This has already been noted in the discussion of operating costs and fixed charges. The total operating costs vary almost directly with the amount of use, but the fixed charges, being computed either wholly or in part on an annual basis, are in a large measure independent of the amount of annual use. The operating costs per hour are, therefore, practically constant, whereas the fixed charges per hour decrease as the annual hours of use increase. This is illustrated in Table 20. Interest decreases more rapidly than depreciation with increasing annual use, as it is computed entirely on an annual basis and is independent of use. With only 100 hours of annual use, the fixed charges constitute 69 per cent and 75 per cent of the total cost per hour for the 2-plow and 3-plow tractors, respectively. With 1,200 hours of use per year, these percentages drop to 21 per cent and 27 per cent. The effect of increasing annual use is shown in Figure 10. Up to 400 hours per year the costs decrease rapidly. Beyond this point the rate of decrease is fairly gradual. The decrease between 100 and 400 hours is 72 cents and $1.21 for the two sizes of tractors and only 15 cents and 27 cents respectively between 400 hours and 1,200 hours. The tractor operator may well give much attention to securing a fuller utilization of his tractor as a means of cost reduction up to 400 hours of work annually. Beyond that point, the amount of annual use becomes increasingly less important in its effect on costs.

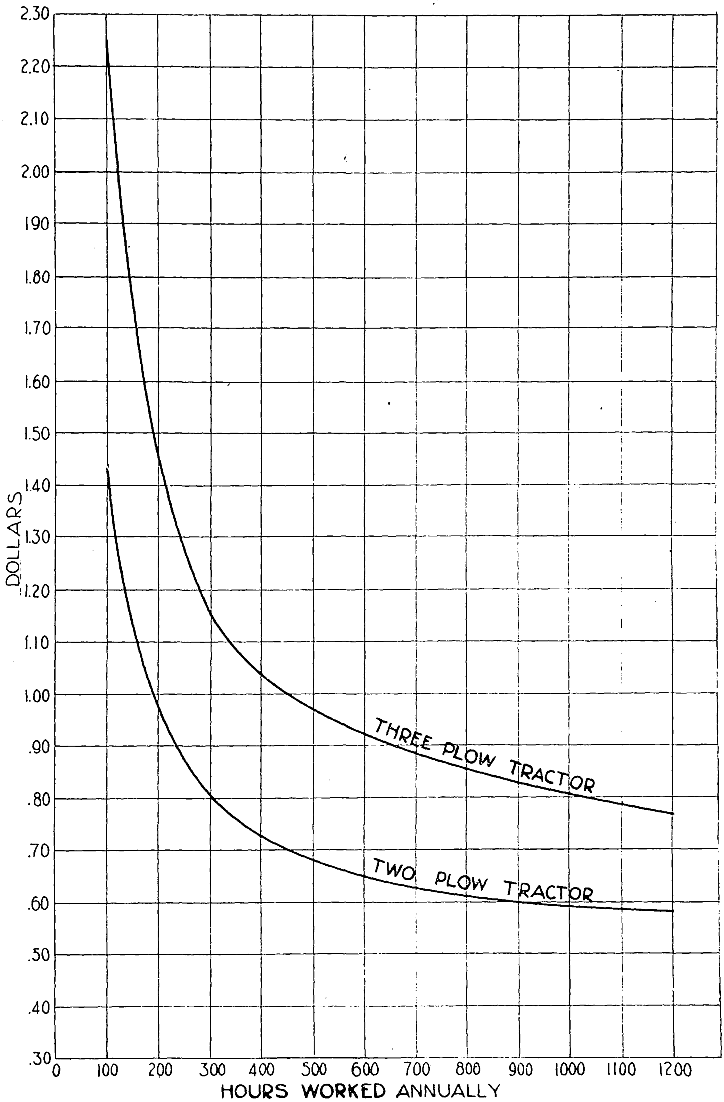

Fig. 10. Relation of Hours Worked Annually per Tractor to Total Cost per Hour
The cost per hour of tractor work decreases rapidly as the hours of annual use increase up to about 400 or 500 hours. Beyond that point additional use affects the cost per hour comparatively little.

The interest and depreciation charge per hour also vary with the purchase price of the tractor. The effect of purchase price on cost per hour is shown in Table 21.

Table 20

Relation of Hours Worked Annually to Cost per Hour of Tractor Work

Hours worked annually	2-plow tractor: Operating cost	Fixed charges: Interest	Fixed charges: Depreciation	Fixed charges: Total	Total cost	3-plow tractor: Operating cost	Fixed charges: Interest	Fixed charges: Depreciation	Fixed charges: Total	Total cost
100	$0.45	$0.34	$0.65	$0.99	$1.44	$0.56	$0.58	$1.11	$1.69	$2.25
200	0.45	0.17	0.35	0.52	0.97	0.56	0.29	0.61	0.90	1.46
300	0.45	0.11	0.24	0.35	0.80	0.56	0.19	0.40	0.59	1.15
400	0.45	0.08	0.19	0.27	0.72	0.56	0.15	0.33	0.48	1.04
500	0.45	0.07	0.17	0.24	0.69	0.56	0.12	0.30	0.42	0.98
600	0.45	0.06	0.14	0.20	0.65	0.56	0.10	0.25	0.35	0.91
700	0.45	0.05	0.14	0.19	0.64	0.56	0.09	0.24	0.33	0.89
800	0.45	0.04	0.12	0.16	0.61	0.56	0.08	0.21	0.29	0.85
900	0.45	0.04	0.12	0.16	0.61	0.56	0.07	0.19	0.26	0.82
1,000	0.45	0.04	0.11	0.15	0.60	0.56	0.06	0.19	0.25	0.81
1,100	0.45	0.03	0.10	0.13	0.58	0.56	0.06	0.17	0.23	0.79
1,200	0.45	0.03	0.09	0.12	0.57	0.56	0.05	0.16	0.21	0.77

In Table 21 an average life of 10 years is assumed and the hour costs are computed on the basis of the average annual hours of use, shown in Table 16. It is apparent that keeping down the purchase price is an important factor in reducing the charges for tractor use.

Table 21

Effect of Variations in the Purchase Price of a Tractor on Charges per Hour for Interest and Depreciation

Price range	2-plow tractor: Purchase price	2-plow tractor: Interest and depreciation	3-plow tractor: Purchase price	3-plow tractor: Interest and depreciation
Lowest price	$ 430	$0.16	$ 800	$0.24
Average price ...	776	0.29	1,335	0.40
Highest price	1,300	0.47	2,400	0.72

Another factor affecting the cost of tractor operation is the age of the tractor. The cost of lubricants and repairs is less for the newer tractors. This is indicated in Table 22. The lowest costs are incurred during the first two years; after four years the lubrication costs were fairly constant. Repair costs increased fairly regularly up to the fourth year. After that they were quite irregular but averaged much higher than for the earlier years. It should be remembered that while the cost of lubricants and repairs are increasing with age, the value of the tractor itself is decreasing through depreciation; hence the interest charge is less. The average interest charge per hour for the first two years for a 2-plow tractor is 15 cents; for the tenth year it is only 2 cents. Corresponding figures for the 3-plow tractor are 21 cents and 2 cents. The increase in the cost of lubricants and repairs is approximately offset by the decreasing interest.

Table 22

Effect of Age of Tractor on Cost per Hour of Lubricants and Repairs

Age of tractor, years	2-plow tractors			3-plow tractors		
	Lubricants	Repairs	Total	Lubricants	Repairs	Total
1-2	$0.05	$0.04	$0.09	$0.07	$0.03	$0.10
3-4	0.08	0.08	0.16	0.09	0.10	0.19
Over 4 ..	0.09	0.14	0.23	0.11	0.15	0.26

This study brought out no significant differences in fuel cost per hour between tractors of different ages. Even when compared for the single operation of plowing, for which the power demand would be more uniform than might be expected of the average, no difference in fuel efficiency due to age was noted. The new tractors consumed slightly more fuel per hour but plowed more land per hour. The fuel cost per acre was practically constant for all ages of tractors. There was, however, a considerable variation in fuel costs owing to differences in fuel used and in the price paid by different operators. The fuel cost per hour with different kinds of fuel, charged at the average price at which they were purchased for the tractors studied, is shown in Table 23. The prices for the different fuels are gas 16½ cents, kerosene 13½ cents, and distillate 8½ cents. The amount of fuel used per hour is 1.92 gallons for 2-plow tractors and 2.54 gallons for 3-plow tractors, the average fuel consumption shown in Table 16. An allowance of one gallon of gasoline to every 20 gallons of total fuel is made in case of both kerosene and distillate, as gasoline is required for starting tractors that operate with low-test fuel. The substitution of kerosene for gasoline reduces the fuel cost per hour by nearly one-fifth and the substitution of distillate practically cuts it in half. The use of low-grade fuel is a matter of considerable economy in case of any tractor that will operate satisfactorily with it.

Table 23

Variations in Tractor Fuel Costs per Hour Due to Kind of Fuel Used

Kind of fuel	2-plow tractor	3-plow tractor
All gasoline	$0.32	$0.42
5 per cent gasoline and 95 per cent kerosene	0.26	0.35
5 per cent gasoline and 95 per cent distillate	0.17	0.23

The price paid for fuel accounts for some variation in costs of tractor operation. As already noted, the price paid for gasoline used in the tractors studied varied from 13 to 20 cents per gallon and of kerosene from 11 to 16 cents per gallon. On the basis of average fuel consumption this would make a difference of from 25 to 38 cents an hour for the 2-plow tractors in case of gasoline and of from 21 to 31 cents per hour for kerosene. Corresponding ranges for the 3-plow tractor are 33 to 51 cents and 28 to 41 cents, respectively, for gasoline and kerosene.

EFFECT OF THE TRACTOR ON FARM ORGANIZATION

The addition of a tractor to the equipment of a farm involves far more than a mere substitution of mechanical power for animal power. In the great majority of cases, when a tractor is purchased for the first time for farm use, the farm is already organized for operation by horse power. The machines are designed for horse use. The crops and livestock are adjusted to the labor supply of the farm under horse operation. The crops grown provide feed for sufficient horses to handle the farm work. The addition of the tractor involves numerous adjustments in the size of farm, the field arrangement, the cropping system—especially in regard to feed crops, cultural practices, amount and kind of livestock raised, the labor organization, the number of work horses, and the machine equipment of the farm. Unless these adjustments are carefully considered and carried out, the tractor may add to the operating expense of the farm without a corresponding increase in the income. Each farmer interviewed was asked what adjustments in farm organization he had made since purchasing his tractor. In some cases they had begun farming with a tractor, so it was impossible to get a record of changes. However, most of the men had some experience on the same farm without a tractor and the adjustments in their farm organization are discussed in the following pages.

Size of Farm

The majority of the farmers interviewed increased the size of their farms, or at least the acreage of crops raised, since the purchase of their first tractor. The extent of this increase is indicated in Table 24. Most of the increase came through the renting of additional land. The new land brought under cultivation was either native pasture or meadows that were broken, wet land that was drained, or wood and brush land that was cleared. Three farmers reported that they dropped small areas of crop land out of cultivation which, on account of topography and irregularity, was not adapted to tractor operation.

Table 24

Change in Size of Farm and Acres Under Cultivation Since Purchase of a Tractor

	Number farms	Per cent of total farms	Average acreage	
			Farms reporting	All farms
Bought additional land	19	6.5	142	9.5
Rented additional land	88	30.2	181	55.0
Brought new land into cultivation	89	30.6	51	15.5
Total	196	67.4	118	80.0

Farm Layout

The changes in farm layout in order better to adapt the farm to tractor use were few in comparison with changes in size. Twelve per cent of the operators reported that they had combined smaller fields in order to have fields large enough for economical tractor operation. Fifteen per cent reported changes in the shape of their fields. Long regular fields make possible effective tractor use. Three per cent of the operators reported clearing, stoning, or draining the land in order to straighten fields, remove obstacles, and make the land better adapted to tractor tillage.

Cropping System

No marked change in cropping systems as the result of the purchase of a tractor was reported. As most of these farms were livestock farms, the crops grown were largely feed crops. Any decrease in the demand for feed resulting from a decrease in work horses was offset by an increase in productive livestock that consumed the feed formerly going to the work horses. The principal change was in seedbed preparation. Most farmers reported that the tractor enabled them to work their land more thoroly than they had been doing with horses.

Livestock

Table 25
Increase in Animal Units* of Productive Livestock Since the Purchase of a Tractor

	No. animal units per farm*		Percentage of change on farms studied	Percentage in state 1921-29†
	Before purchase	Now		
Dairy cows	9.8	10.3	4.5†	3.2†
Beef cows	2.5	1.8	27.8†	‡
Other dairy cattle	3.9	4.3	11.2†	‡
Other beef cattle	1.5	1.6	3.8†	‡
Total cattle	17.7	18.0	1.6†	—7.6
Sheep	1.1	1.9	71.0†	59.2†
Swine	1.4	1.5	8.8†	49.2†
Poultry	1.2	1.3	7.4†	‡
Total productive livestock	21.4	22.7	6.0†	2.9†§

* One cow, 2 head other cattle, 7 sheep, 5 hogs, or 100 chickens are considered an animal unit.

† Based on numbers of livestock on Minnesota farms as reported in U.S. Dept. of Agr. Yearbooks for 1921 and 1930.

‡ Data not available for the state.

§ Not including chickens—no state figures available for 1921.

Some increase in numbers of productive livestock maintained after the tractors were purchased was reported by the farmers interviewed. The amount of increase is shown in Table 25. The rate of increase in livestock for the state as a whole is also given for comparison. An eight-year period is adopted because eight years was the average time tractors had been used by the farmers reporting. Altho the rate of increase of productive livestock on the farms studied was more rapid than for the state as a whole, the acreage of these farms had been increased approximately 25 per cent since the tractor was purchased. Some farmers said that the use of the tractor reduced the amount of time spent on horses and speeded up field operations to such an extent that they had more time for handling productive livestock. The data obtained in this study indicate that any time saved through the use of the tractor was used to handle more acres of crops rather than to care for any considerable increase in productive livestock. Apparently the tractor did not greatly affect the livestock organization.

Labor

One of the important changes in the farm organization resulting from the introduction of the tractor is the adjustment in the labor supply and its utilization. Each tractor operator was asked whether he was hiring more or less labor since the purchase of the tractor and whether he was using more or less family labor. The answers are summarized in Table 26.

Table 26

Changes in Farm Labor Supply After the Purchase of a Tractor

	Farms reporting		Average days per farm	
	Number	Percentage	Farms reporting	All farms
Hired less labor	131	45.0	140	63
Hired more labor	1	0.3	300	1
Used less family labor	20	7.0	71	5
Used more family labor	0	0	0	0
Net decrease in days of labor used per farm				67

Forty-five per cent of all operators hired less labor after purchasing the tractor and only one man, who rented an additional 160 acres of land, hired more. There was some decrease in the amount of family labor used. A net saving of 67 days of labor was effected in spite of the fact that the acres per farm had been increased about 25 per cent and the livestock 6 per cent.

This saving of labor seems high in view of the fact that the average number of days of tractor drawbar work per year was only 346 per farm. At most tractor operations, the saving of man labor does not exceed 50 per cent of the same work performed by horses. This saving is in line with the results of similar studies in other states. Myers[12] reports a saving of 2.4 months of man labor on general farms where tractors are used 295 hours per year for drawbar work. Tolley and

[12] Myers, W. I. An Economic Study of Farm Tractors in New York. Cornell (N. Y.) Agr. Expt. Sta. Bull. 405, p. 103. 1921.

Church[13] report a saving of 66 days per year when tractors were used 35 to 40 days. Gross and Waller[14] report a saving of 4.5 months by tractors used for 230 hours of field work and 5.8 months when the tractors were used 345 hours in the field. Gilbert[15] found a reduction of 4.8 months of man labor on general farms using tractors 305 hours for drawbar work. Altho there may be a tendency on the part of some farmers to overestimate the saving in man labor resulting from the use of the tractor, the consistency with which these different studies report a larger saving than could be effected directly by substituting the tractor for horses for the field operations indicates that there must be in addition some indirect labor economies. The use of the tractor by speeding up the work may make it possible to perform operations at the most opportune time and thus reduce the number of operations necessary. It is also possible that considerable time may be saved in working the more distant parts of the farm. The tractor can be left in the field and the farmer, using his automobile to make the trips back and forth, can save the time that would be required to drive the teams to and from the barn. A saving is possible also in using the tractor for belt work. The farmer with his own tractor may perform this work at a time that fits into his labor program to best advantage. The livestock farmer often saves considerable time by grinding his own grain rather than hauling it to a custom mill and either waiting his turn or making a second trip to get the feed. These indirect savings of labor are of considerable importance.

Table 27

Change in the Length of the Work Day and of the Field Day Since the Purchase of a Tractor

Change reported	Farms reporting		Average hours per day	
	Number	Percentage	Farms reporting	All farms
Shorter work day	106	36.4	0.90	0.34
Longer work day	31	10.7	1.90	0.16
Net average decrease in work day				0.18
Shorter field day	27	9.3	1.60	0.14
Longer field day	128	44.0	1.70	0.73
Net increase in field day				0.59

In addition to changes in the number of days of labor used on the farm after the purchase of the tractor, changes in the length of the work day and of the field day were reported. These are shown in Table 27. More farmers report a shorter working day than report a

[13] Tolley, H. R. and Church, L. M. Tractors on Southern Farms. U. S. Dept. of Agr. Farmers' Bull. 1278, p. 19. 1922.

[14] Gross, E. R. and Waller, A. G. Tractor Farming in New Jersey. N. J. Agr. Expt. Sta. Bull. 386, p. 22. 1923.

[15] Gilbert, C. V. An Economic Study of Tractors on New York Farms. Cornell (N. Y.) Agr. Expt. Sta. Bull. 506, p. 56. 1929.

longer one, but those reporting a longer day report a greater change. When the reports are averaged for the group they indicate little change in the length of work day. It is possible to put in as long a work day with a tractor as the operator wishes and on a number of farms some night work was done. Usually in such cases a shift of drivers enables the farmer to get full use of his tractor without overworking himself or his workers.

Many of the tractor operators report a longer work day in the field than was possible with horses. The time formerly spent caring for the work horses can be spent in the field. Some farmers work less hours in the field as they are able to accomplish more in the same length of time than they could have done with horses and the time saved is either used for other tasks, such as care of livestock, or for leisure.

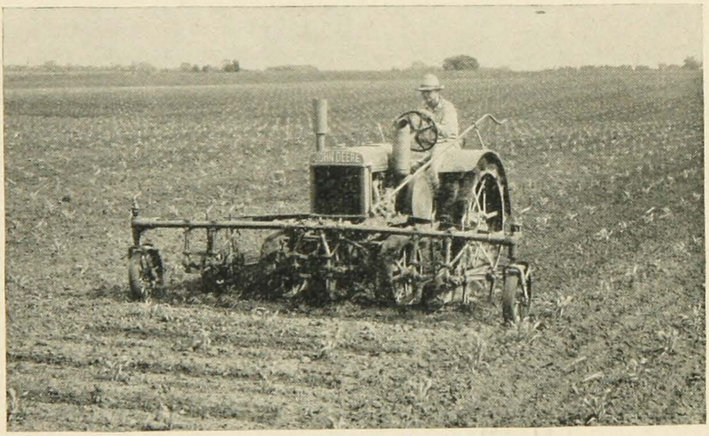

Fig. 11. Cultivating Corn with a General-Purpose Tractor

General-purpose tractors are made to plant and cultivate two, three, or four rows of corn or other row crop at a time. The planter is attached to the tractor or drawn behind it and a cultivator taking the same number of rows as the planter is attached to the tractor. In most instances this equipment may be readily attached and detached to make the tractor available for other work.

Some comparisons showing the saving in man labor when performing certain field operations with a tractor over that by horse power is shown in Table 28. The amount of man labor per acre has been obtained from detailed farm account studies conducted by the Division of Agricultural Economics, of the Minnesota Agricultural Experiment Station, covering the three regions of the state where the tractor records were obtained. The labor expenditures used are standards[16] representing the accomplishment of farmers ranking well above the average in labor efficiency. The sizes of implements and teams are those most com-

[16] Pond, G. A. A Study of Dairy Farm Organization in Southeastern Minnesota. Minn. Agr. Expt. Sta. Tech. Bull. 44, p. 42. 1926.

monly used by the farmers who used their labor most effectively. It is recognized that by the use of larger implements and of 6-, 8-, 10-, or 12-horse teams the man labor for horse operation might be reduced to a basis comparable with that of the tractor. These comparisons are based, however, on the horse power units in common use in the areas studied rather than on the exceptional practice. The amount of man labor per acre for performing the specified operations with tractors is computed from the data presented in Table 14. The size of tractor most commonly used was chosen for this comparison. In general, the 2-plow tractors effect an average saving of at least one-fourth in man labor as compared with horse operation and the 3-plow tractors a saving of nearly half. In evaluating the comparisons for disking, one should note that a single disk is used with horses and a tandem disk with the tractor. If the work of a tandem disk is assumed to be equal to 2 single diskings, the savings for the 2-plow and 3-plow tractors would be 58 per cent and 70 per cent, respectively,

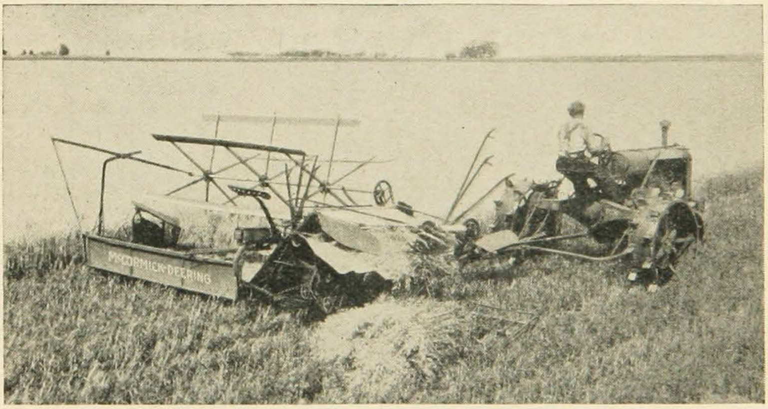

Fig. 12. Tractor Binder in Operation

Power for the cutting and binding mechanism is transferred directly from the tractor engine to the binder by means of the power take-off shaft. With machinery designed for power take-off operation, tractor power is especially desirable for operating such equipment as the grain binder, mower, corn picker, and potato digger.

instead of the 16 per cent and 42 per cent shown. In these comparisons, only time actually spent in the field or going to and from the field is considered. There may also be some additional saving in man labor in that the daily servicing of the tractor did not require as much time as ordinarily would be spent daily in caring for a four- or five-horse team. This labor is computed on the basis of a comparison between the largest size of horse hitch in common use in the areas studied and the two sizes of tractors for which records were obtained. Much of this saving might be effected by the use of eight-, ten-, and twelve-horse hitches. On the smaller farms, especially in southeastern Minnesota, that might not be practicable because the limited crop acreage would not furnish sufficient employment to utilize the services of so many horses advantageously. On the larger farms of western and northwestern Minnesota, the large multiple hitches might be entirely practicable but no data are available from this study to indicate the relative economy of such hitches as compared with tractors as a source of power.

Table 28

Comparison of Amount of Man Labor Used per Acre in Performing Field Operations with Horses, 2-Plow Tractors, and 3-Plow Tractors

	Size and kind of implement	Power used	Hours per acre	Saving over horse operation, per cent
Plowing	2 14-in. bottom gang plow	5 horses	2.00	...
	2 14-in. bottom gang plow	2-plow tractor	1.43	28.5
	3 14-in. bottom gang plow	3-plow tractor	1.00	50.0
Disking	8-ft. single disk	4 horses	0.50	...
	8-ft. tandem disk	2-plow tractor	0.42	16.0
	10-ft. tandem disk	3-plow tractor	0.29	42.0
Spring-tooth harrowing	7-ft. spring-tooth harrow	4 horses	0.60	...
	8-ft. spring-tooth harrow	2-plow tractor	0.48	20.0
	10-ft. spring-tooth harrow	3-plow tractor	0.34	43.3
Harrowing	22-ft. spike-tooth harrow	4 horses	0.20	...
	26-ft. spike-tooth harrow	2-plow tractor	0.13	35.0
	26-ft. spike-tooth harrow	3-plow tractor	0.11	45.0
Seeding	10-ft. drill	4 horses	0.50	...
	10-ft. drill	2-plow tractor	0.36	28.0
	14-ft. drill	3-plow tractor	0.25	50.0
Cutting grain	8-ft. binder	4 horses	0.75	...
	10-ft. binder, power take-off	2-plow tractor	0.33	56.0
	10-ft. binder, power take-off	3-plow tractor	0.32	57.4
Cultivating corn	2-row cultivator	4 horses	0.70	...
	2-row cultivator	2-plow tractor	0.50	28.6

Other Power Costs

One of the most direct adjustments in the farm organization resulting from the introduction of the tractor is a reduction in the number of work horses. The decrease in work horses on the farms studied is shown in Table 29. The average decrease per farm was 1.9 head, or 21 per cent. As the acreage per farm and the amount of productive livestock maintained has been increased, this figure hardly gives an adequate picture of the actual reduction. Each farmer was asked how many work horses would be required to operate his farm under the present organization without a tractor. The reduction on this basis was 3.6 horses per farm, or 33.6 per cent. The possible reduction was greatest on the larger farms in the small grain section in the northwestern part of the state. At the time of this study, tractors had not come into general use in cultivating corn in the corn growing section in southwestern Minnesota. The use of the tractor for this purpose would make possible further reduction of work horses. As the price of horses has been declining during most of the time since these farmers purchased their tractors[17] it is possible that more horses are maintained on these farms at the present time than would be the case if horses could be sold more advantageously. The relation between crop acreage and the number of horses per farm displaced by tractors is shown in Table 30.

Table 29

Reduction in Number of Work Horses per Farm Following the Purchase of a Tractor

	Southeast	Southwest	Northwest	All areas
Work horses per farm before purchase of tractor	7.5	9.0	10.9	9.1
Work horses per farm now	5.9	6.8	8.5	7.1
Actual decrease in number of work horses	1.6	2.2	2.4	2.0
Percentage decrease in number of work horses	21.3	24.5	22.0	22.0
Work horses needed for present organization without tractors	8.1	9.3	14.5	10.7
Potential decrease in number of work horses, present organization	2.2	2.5	6.0	3.6
Percentage decrease in work horses, present organization	27.2	26.9	41.4	33.6

The displacement of horses by tractors is very closely proportionate to the crop acreage. For every additional 74 acres in crops, approximately one less horse is needed after the tractor is purchased. The relation is fairly constant regardless of the size of the farm.

Table 30

Relation of Crop Acreage per Farm to Number of Horses Displaced by Tractors

Crop acreages			Work horses per farm			Crop acres per horse displaced
Group	Average	No. of farms	At present	No. needed without tractor	Displaced by tractor	
Under 100	79	24	4.3	5.3	1.0	79
100-199	145	108	5.5	7.6	2.1	69
200-299	245	79	7.2	10.1	2.9	84
300-399	336	34	8.2	12.6	4.4	76
400-499	442	18	10.2	16.3	6.1	72
500 and over	772	28	11.7	22.6	10.9	71
All farms	268	291	7.1	10.7	3.6	74

In addition to reducing the number of work horses per farm after purchasing the tractor, most farmers reported a reduction in cost of feed for the horses retained. The average reduction was 20 per cent

[17] Yearbook of the U. S. Dept. of Agr., 1930, Table 435, p. 895.

of grain and 11 per cent of hay per horse. On the other hand, an increase of 29 per cent in pasture days is reported. Apparently the tractor is used for the heavier operations. The horses are used more largely for lighter work, require less hay and grain, and can utilize more pasture.

It might be expected that with tractors used for the heavier work and the horses fed less and spending more time in the pasture that the amount of man labor spent in caring for a work horse would be less. These farmers reported exactly the same number of hours per horse daily as before the purchase of the tractor. It is probably true that each horse actually received less attention than before. However, there are certain operations, such as feeding, for which the total time spent would be changed very little by a change of two or even three in the number fed. The charge per horse would therefore increase and tend to offset any decrease due to less time spent harnessing or currying horses or that the horses were in pasture more of the time and hence received attention fewer days.

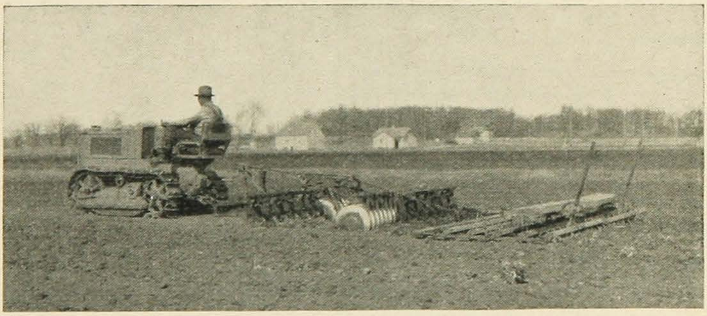

Fig. 13. Disking and Harrowing in One Operation

The tractor should be loaded to its optimum capacity for most economical operation. This may be done by supplying an implement of sufficient size to provide this load or by combining two or more different kinds of implements and performing more than one operation at a time. The latter method has real possibilities on the average farm where the use of large scale equipment is impractical.

The tractor operators were asked regarding changes in the age, working life, weight, and value of their horses since purchasing a tractor. A summary of their answers is presented in Table 31. The 16.5 per cent increase in the age of horses has little significance, as the average age of all horses on farms has been increasing during the same period.[18] It seems reasonable to assume that with a tractor for the heaviest work, it might be possible to get along with older horses for the lighter work but these figures do not support that assumption conclusively. They do, however, indicate that more years of service

[18] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262, p. 17. 1930.

may be expected of the same horse if the tractor carries the burden of the heavy work. It might also be assumed that lighter horses would answer the purpose on a farm where a tractor is used, but such did not prove the case on these farms. The lower value of horses on hand now as compared with those used before the tractor was purchased has no significance, as the period covered is one of declining horse prices, as has already been noted, and the increasing age alone would account for most of the difference.[19]

Table 31

Average Changes in the Age, Working Life, Weight, and Value per Head of Work Horses on Farms Since the Purchase of a Tractor

	Before purchase of tractor	After purchase of tractor	Change since purchase of tractor	
			Amount	Percentage
Average age of work horses, years	9.7	11.3	+1.6	16.5
Average working life of work horses, years	14.4	16.6	+2.2	15.3
Average weight of work horses, pounds	1,376	1,376	0	0
Average value per head of work horses	$102	$94	—$8.00	—7.8

It is difficult to compute exactly the reduction in cost of maintaining work horses due to the substitution of the tractor for horse power since most of the factors that make up the horse costs in Minnesota are furnished by the farm and do not represent direct cash outlay. It is, however, possible to apply market prices to these factors and arrive at their alternative market value. The average amounts of feed per head for work horses, as found in detailed accounting studies,[20] covering the same three sections of the state as were covered in the survey are 3,200 pounds of grain, 5,200 pounds of hay, and 56 days of pasture. The average state price[21] of the oats and corn for the period of the tractor survey, April 1, 1928, to March 31, 1929, were 42 cents and 77 cents, respectively. The corresponding price[22] of timothy hay was $10.60 per ton. Unpublished data from these studies indicate that the usual charge for pasture in these areas is 5 cents per horse per day. A statement of the annual cost of feed for a work horse on the basis of these quantities of feed and these prices is shown in Table 32. The cost is also shown with a reduction in the quantity of hay and grain and the increase in the use of pasture that was reported when the

[19] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262, p. 17. 1930.

[20] Pond, G. A. A Study of Dairy Farm Organization in Southeastern Minnesota. Minn. Agr. Expt. Sta. Tech. Bull. 44, p. 92. 1926.

Pond, G. A. and Tapp, J. W. A Study of Farm Organization in Southwestern Minnesota. Minn. Agr. Expt. Sta. Bull. 205, p. 64. 1923.

Sallee, G. A., Pond, G. A., and Ruud, C. O. A Preliminary Report of Livestock Costs and Returns. Farm Accounting Route, Polk County, p. 9. 1928.

[21] Crops and Markets, vol. 6 and 7, monthly farm price reports.

[22] *Ibid.*

tractor was used. It is assumed that the grain fed is one half oats and one half corn. In addition to having less horses to feed when a tractor is used, there is a reduction of $10.77 in the cost of feeding each of the remaining horses.

Table 32

Comparison of Feed Cost per Work Horse Before and Since the Purchase of a Tractor

(Based on average Minnesota prices of feed, April 1, 1928–March 31, 1929)

Kind and price of feed	Without tractor		With tractor	
	Amount	Value	Amount	Value
Oats at 42 cents per bushel, lb.	1,600	$21.00	1,280	$16.80
Corn at 77 cents per bushel, lb.	1,600	22.00	1,280	17.60
Hay at $10.60 per ton, lb.	5,200	27.56	4,628	24.53
Pasture at 5 cents per day, days	56	2.80	72	3.60
Total feed cost		$73.36		$62.53
Reduction after purchase of tractor	....	.....	....	$10.83

Another saving in horse costs is a reduction in the time spent caring for the horses resulting from the decrease in number. The same studies from which the data on feeds were obtained indicate an average of 86 hours of man labor annually per horse. If valued at 30 cents per hour, the rate used previously in this study, the labor charge per year for caring for a horse would be $25.80. Some reduction in depreciation on horses results from the decrease in number and also from the longer working life. If we assume the average value of a work horse to be $111[23] at three years of age, the beginning of its working life, the average annual depreciation would be $7.71 if no tractor is used and $6.69 if a tractor is used. The average annual interest charge at 6 per cent on $94, the average value of horses now on farms, would be $5.64. Other charges, such as taxes, insurance, and shelter, might be reduced with the reduction of number of work horses. The first two are, however, minor items. The shelter charge may be of more importance but once the shelter is provided, a reduction in the number of horses does not eliminate it, altho it may be shifted to some other class of livestock. A summary of the reductions in horse costs effected by use of the tractor is shown in Table 33.

On the basis of these computations, the use of a tractor makes possible a reduction of $489.17 in the items of horse costs specified. Obviously, the amount of this reduction differs widely between farms because of differences in size that affect both the possible number of horses that can be displaced by the tractor and the number still needed. Cost reductions computed on this basis for each of the groups shown in Table 30 are presented in Table 34.

[23] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262, p. 19. 1930.

Table 33

Average Annual Reduction in Specified Items of Estimated Horse Costs Made Possible by the Use of the Tractor on Farms Studied

Items		Total deduction
Decrease in feed charge	3.6 horses displaced at $73.36	$264.10
	7.1 horses retained at 10.83	76.89
Total decrease in feed charge		$340.99
Decrease in labor charge	3.6 horses displaced at 25.80	92.88
Decrease in depreciation charge ..	3.6 horses displaced at 7.71	27.76
	7.1 horses retained at 1.02	7.24
Decrease in interest charge	3.6 horses displaced at 5.64	20.30
		$489.17

The larger the crop acreage the larger is the number of horses that can be displaced and also a greater reduction in horse costs is possible. The total reduction in horse costs averages approximately $136 for each horse displaced but varies between the different size groups. Part of this $136 is the cost of maintaining the horse displaced and part is the saving in the cost of maintaining the horses retained. The total cost of feed, labor, interest, and depreciation for a work horse on a farm operated with animals, as shown in this study, was $112.51. The farmers interviewed estimated that their costs were $11.85 per head less when the tractor was used. The total reduction of $136 is a combination of these two factors.

Table 34

Average Annual Reduction in Specified Items of Estimated Horse Costs Made Possible by the Use of a Tractor on Farms of Different Sizes

(Based on feed prices, April 1, 1928 to March 31, 1929)

Crop acres per farm		Reduction in items of cost				
Group	Average	Feed	Labor	Depreciation	Interest	Total
Under 100	79	$119.93	$25.80	$12.18	$ 5.64	$163.47
100-199	145	213.63	54.18	21.80	11.84	247.27
200-299	245	290.72	74.82	29.70	16.36	411.60
300-399	336	411.59	113.52	42.28	24.82	592.21
400-499	442	557.97	157.38	57.43	34.40	807.18
500 and over	772	926.33	281.22	34.40	61.48	1,365.00
All farms	268	$340.99	$92.88	$35.00	$20.30	$489.17

Another important factor affecting the reduction in horse costs is the price of feeds and labor, and the depreciation of horses. The data presented in Table 34 have been recomputed on the basis of Minnesota farm prices for February, 1931,[24] and are shown in Table 35.

The prices are as follows: Oats, 24 cents per bushel; corn, 46 cents per bushel; hay, $9.00 per ton; three-year-old work horses, $91; average value of all work horses on farms in the state, $77; and man labor, 20 cents per hour. The value of three-year-old work horses was computed from the value of all work horses on the assumption that the

[24] Crops and Markets, Vol. 8, No. 3, pp. 90-92. March, 1931.

relation between these two prices would be the same as during the previous period. The rate of man labor was reduced in line with decreases in farm wages. This use of present prices (February, 1931) results in a decrease of approximately 30 per cent in the reduction as compared with that computed on the basis of the prices in effect during the period of the study. The lower the price of feeds, horses, and other elements of cost of horse work the less will be the saving effected by the substitution of tractor power for animal power unless there is a proportionate reduction in the cost of tractor power.

Table 35

Average Annual Reduction in Specified Items of Estimated Horse Costs Made Possible by Use of a Tractor on Farms of Different Sizes

(Based on February, 1931, feed prices)

Crop acres per farm		Reduction in items of cost				
Group	Average	Feed	Labor	Depreciation	Interest	Total
Under 100	79	$ 80.67	$17.20	$ 9.93	$ 4.62	$112.42
100-199	145	145.32	36.12	17.89	9.70	209.03
200-299	245	197.99	49.88	24.38	13.40	285.65
300-399	336	281.82	75.68	34.70	20.33	412.53
400-499	4[illegible]2	382.73	104.92	47.12	28.18	562.95
500 and over	772	639.40	187.48	78.72	50.36	955.96
All farms	268	$233.24	$61.92	$28.71	$16.63	$340.50

The reduction of horse costs as the result of tractor use, computed for different prices of oats, corn, and hay is presented in Table 36. As decreases in feed costs comprise more than two-thirds of the reduction in horse costs shown in Tables 32, 33, and 35, and as the other items are relatively more constant, only reduction in the cost of grain and hay is shown.

Table 36

Reduction in Annual Cost of Hay and Grain for Work Horses Made Possible by Use of Tractor, Computed for Different Prices for Oats, Corn, and Hay

Oats			Corn			Hay		
	Reduction			Reduction			Reduction	
Price per bushel	Per horse displaced	Per horse retained	Price per bushel	Per horse displaced	Per horse retained	Price per ton	Per horse displaced	Per horse retained
$0.20	$10.00	$2.00	$0.30	$ 8.57	$1.71	$ 6.00	$15.60	$1.72
.25	12.50	2.50	.40	11.43	2.29	7.00	18.20	2.00
.30	15.00	3.00	.50	14.29	2.86	8.00	20.80	2.29
.35	17.50	3.50	.60	17.14	3.43	9.00	23.40	2.57
.40	20.00	4.00	.70	20.00	4.00	10.00	26.00	2.86
.45	22.50	4.50	.80	22.86	4.57	11.00	28.60	3.15
0.50	25.00	5.00	0.90	25.71	5.14	12.00	31.20	3.43

For example, a farmer may be operating his farm with 8 horses. The use of a tractor may make it possible to reduce the number of horses to 5. With oats at 20 cents, corn at 30 cents, and hay at $6.00, the reduction in feed cost would be \$102.51 for the 3 horses displaced and for the remaining 5 horses of \$27.15, a total reduction of \$129.66.

$$(3 \times \$10.00) + (3 \times \$8.57) + (3 \times \$15.60) = \$102.51$$
$$(5 \times \$2.00) + (5 \times \$1.71) + (3 \times \$1.72) = \$27.15$$
$$\$129.66$$

With oats at 35 cents, corn at 70 cents, and hay at \$12, the savings would be as follows:

$$(3 \times \$17.50) + (3 \times \$20.00) + (3 \times \$31.20) = \$206.10$$
$$(5 \times \$3.50) + (5 \times \$4.00) + (5 \times \$3.43) = \$54.65$$
$$\$260.75$$

The reduction in feed costs would be twice as great with the second set of prices as with the first. In the same way the data in Table 36 can be used to compute the possible saving with any given numbers of horses displaced and retained and with any combination of feed prices. These data may be used by a farmer who is considering the purchase of a tractor. By selecting the prices that apply to his particular situation, he may compute the probable reduction in cost of the horse feed that can be effected through the substitution of a tractor for some of his animal power.

The foregoing computations are based on the assumption that the elements of cost involved could be made to yield their market price in some other use. This might be possible in case of labor by shifting it from work horses to productive livestock. Otherwise the saving indicated might be lost, as most of the time spent on horses is performed before or after a day's work in the field and hence is not available, or at least not fully so, for crop work. The full saving in feed cost indicated is only possible in case the feed saved can be used in some other way that will not reflect unfavorably on the price of those things upon the sale of which the farmer is dependent for his income. The release of large acreages of crop land formerly used for raising feed for horses that have been displaced by tractors is, in the opinion of some students of the subject, an important factor in the agricultural depression.[25] The computations presented in the foregoing tables serve merely to illustrate a method by which the farmer might analyze his power problem and determine some of the savings in horse costs that would be possible if he were to displace some of his animal power with tractor power. Certain modifications would doubtless be necessary in applying this method to any individual farm.

[25] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262, pp. 30-33. 1930.

Machine Equipment

The purchase of a tractor necessitates the purchase of special tractor equipment to be used with it if the tractor is to be operated advantageously. Some machinery designed for horse power can be used fairly satisfactorily with a tractor, but in most cases the most effective use of the tractor is obtained with machines adapted to tractor power, or at least with special hitches or attachments which adapt them to such use. If the tractor is to be used for belt work, additional equipment is needed that would not be used at all with horse power. The amount of additional equipment bought especially for tractor use on the farms studied is reported in Table 37. Implements for seedbed preparation are most frequently reported, altho nearly half the farms bought some type of harvesting machinery. As some second-hand machinery was purchased, the price is lower than if only new machines had been bought. The most common type of belt equipment bought for use with the tractor is the feed grinder, altho in terms of cost the thresher is by far the more important.

Table 37

Number of Farms Reporting the Purchase of Special Tractor Machinery, Number and Average Price of Machines Bought, and Average Cost per Farm for Such Machinery

Machine	Percentage of farmers reporting purchase	Number of machines purchased	Average purchase price of machine	Average cost per farm (all farms)
Drawbar machinery				
Plow	97.9	304	$ 128.57	$ 134.32
Disk harrow	56.4	185	72.11	45.82
Spring-tooth harrow	54.6	161	70.91	39.23
Spike-tooth harrow	32.6	97	29.18	9.73
Field cultivator	4.8	15	107.40	5.54
Packer	2.7	8	82.00	2.25
Grain drill	5.2	15	193.47	9.97
Grain binder	37.1	123	191.73	81.04
Combine-harvester	2.1	6	2,094.17	43.18
Corn cultivator	2.1	6	91.67	1.89
Corn picker	8.6	25	364.80	31.34
Hay machinery	1.4	...	....	2.05
Potato machinery	1.0	...	....	3.16
Miscellaneous machinery	3.4	...	......	5.57
Total drawbar machinery				$ 415.09
Belt machinery				
Silage cutter	27.8	81	262.89	$ 73.18
Corn shredder	12.0	35	327.92	39.44
Corn sheller	8.2	24	407.58	33.62
Feed grinder	52.6	153	64.69	34.01
Thresher	39.9	116	1,101.02	438.89
Wood saw	22.3	65	23.14	5.17
Total belt machinery	...	...	....	624.31
Total machinery	...	...	....	$1,039.40

Some comparisons of the total cost of special tractor equipment per farm in different parts of the state are shown in Table 38. The total cost of drawbar machinery increases with the size of farm, but not quite so rapidly, so the cost per crop acre is less on the larger farms. In case of belt machinery, there is little relation between size of farm and total investment in special tractor machines. There is nearly as large an investment per farm on the small farms as on the large ones. The cost of this belt machinery per crop acre decreases rapidly as the crop acres per farm increase. One reason for the comparatively high investment in belt machinery on the smaller farms is that more livestock is maintained in proportion to the size of farm and much of this belt machinery is used in preparing crops for livestock consumption.

Table 38
Cost of Special Tractor Machinery per Farm and per Crop Acre on Farms Studied

Section of state	Crop acres per farm	Cost of special tractor machinery per farm			Cost of special tractor machinery per crop acre		
		Drawbar	Belt	Total	Drawbar	Belt	Total
Southeastern ...	146	$263.08	$568.13	$ 831.21	$1.80	$3.89	$5.69
Southwestern ...	236	391.33	664.37	1,055.70	1.66	2.81	4.47
Northwestern ...	425	595.14	648.84	1,243.98	1.40	1.53	2.93
All areas	269	$415.09	$624.31	$1,039.40	$1.54	$2.32	$3.86

Studies by the Agricultural Engineering Section of the Iowa Agricultural Experiment Station[26] indicate the annual costs of machines bought for tractor use, as reported in this survey, average 16 per cent of the purchase price. Sixteen per cent of the first cost of the machinery bought by these farmers is $166.30 per farm. This covers only the machines bought especially for use with the tractor. In addition, an annual cost would be incurred for the machinery designed for animal power. The farmer who is considering the purchase of a tractor must keep in mind the fact that in order to use that tractor effectively he must purchase special tractor equipment. This equipment may cost as much as the tractor itself or more. The annual cost of this machinery is a substantial addition to the farm expense. To a certain extent the purchase price of some of this equipment can be shared with neighbors through co-operative ownership. Some of the annual costs can be offset by the receipts for custom work done with this machinery.

It might be supposed that the purchase of special machinery for use with the tractor might make it possible to dispose of some of the machinery already on the farm. Forty farmers, less than 14 per cent of those included in this study, report machinery that has been dis-

[26] Davidson, J. B. Life Service and Cost of Service of Farm Machinery. Iowa Agr. Expt. Sta. Bull. 260, p. 275. 1929.

carded as the result of the tractor purchase. These 40 men report discarding 59 machines, of which 37 were plows. Forty-one of these 59 machines were sold, 11 were junked, and 7 were reported as on hand but not used. Apparently most of the machinery on the farm when the tractor is purchased is retained for occasional use. The importance of special tractor machinery in fitting the tractor to the farm will be discussed more fully later.

FITTING THE TRACTOR TO THE FARM

Selecting the Tractor

The first and perhaps the most important consideration in fitting the tractor to the farm is the proper selection of the tractor. The tractor market offers a large variety of types and sizes from which to choose. No doubt, one particular type and size will fulfill the requirements on an individual farm better than some other. It is, therefore, highly important that such characteristics of the various tractors, as versatility, power, and adaptation to the work to be performed, be studied carefully before a selection is made.

It has already been shown that there is a definite relationship between the cost of performing certain operations and the size of the tractor. This is due to the fact that the most economical operation occurs when the tractor is working at its optimum capacity (at which the power cost per unit of work is least) which is usually very near to its rated capacity. If, therefore, most of the operations which the tractor is expected to perform require only about 10 horse power, it would be unwise to purchase a three-plow tractor. In the plowing and disking operations a sufficiently large machine may be provided on most any farm where a tractor is used to provide a load that is most efficient for a three-plow tractor. Where enough such work is to be done, the larger tractor may save enough time over a two-plow tractor, as is shown in Table 14, to more than off-set the additional cost of power by using the larger tractor on the jobs requiring only a small amount of power.

Table 5 shows that 54 per cent of all the tractors included in this study are the three-plow and 42 per cent are the two-plow size. The three-plow size predominates in northwestern Minnesota, 65 per cent being of this size. In this region, 7 per cent are larger than three-plow. In southwestern Minnesota the two-plow size predominates slightly, comprising 54 per cent of the total studied in that area. Two-plow and three-plow tractors are evenly divided in the southeast section.

On 158 of the farms included in this survey one or more tractors had been used before the tractor now in use was purchased. In Table 39 the sizes of the tractors owned previously are compared with those now in use. We find from these data a tendency toward the use of the three-plow tractor and away from the very large tractors and the two-plow size. Out of the 47 present owners of two-plow tractors in this group, 40 had this size previously and only 7 changed to this size from a larger size. At present 109 owners, or 67 per cent of those owning tractors previously, have three-plow tractors. Of this number only 17 per cent formerly owned three-plow tractors and 83 per cent changed from the two-plow size to the three-plow size.

Table 39
Sizes of Tractors Owned Now Compared With Sizes of Those Previously Owned on the Same Farms

	Southeast		Southwest		Northwest		All areas	
	Previous	Present	Previous	Present	Previous	Present	Previous	Present
2-plow ..	40	12	47	25	36	10	123	47
3-plow ..	7	36	6	28	11	45	24	109
4-plow ..	..	2	..	..	..	..	...	2
Larger ..	3	..	..	..	8	..	11	...

These data give some indication of the trend in the past with regard to changes in size of tractors. The present situation with regard to size is shown in Table 5. Forty-two per cent of all of the tractors studied are two-plow, 54 per cent are three-plow, and 4 per cent are larger than three-plow.

To obtain some idea regarding the intentions of present owners with regard to the size of their future tractors, the data given in Table 40 were obtained. Answers to questions concerning their intentions in this regard were obtained from 261 operators. Sixty-seven per cent stated that they intended to purchase the same size machine they are operating at present, 31 per cent intended to purchase a larger size, and only 2 per cent a smaller size. These figures indicate that the trend will probably be very much like it has been in the recent past and that the number of tractors of the three-plow size and larger will soon far exceed the two-plow size.

Out of 173 who intend to retain their present size, 114 do not intend to purchase another make, and 59 prefer to make a change.

Table 40
Kind and Size of Tractors That Present Owners Intend to Purchase in the Future

	Number				Per cent
	Southeast	Southwest	Northwest	All areas	Total
Larger	25	21	36	82	31
Smaller	3	1	2	6	2
Same size	60	60	53	173	67
Same make	40	41	33	114	..
Other make ...	20	19	20	59	..

Another factor that will influence the size of tractors in the future is the recent and rapid increase in the manufacture of general-purpose tractors. While the term "general-purpose" is used by one manufacturer as the trade name of its particular tractor, it is used in this bulletin to designate tractors, regardless of make, that are designed especially for row crops and for a relatively large variety of operations. Since this survey was completed several manufacturers have put general-purpose tractors on the market. When the survey was taken only one manufacturer had been selling this type of tractor and not enough were in the field to influence materially the intentions of present owners. The general-purpose tractor is made in both the two-plow and the three-plow sizes.

Some manufacturers have made changes in their standard three-plow tractors, resulting in additional power, so they are capable of pulling four plows under average conditions. Because of these and other influences it is difficult to forecast the trend in tractor sizes in the future. No doubt a large number of general purpose tractors will be in use. As these tractors are capable of performing a larger number of operations than can the standard type, they may be used to better advantage on small farms and on general farms where drawbar power is needed for a large variety of operations. This will tend to increase the number of small tractors. It is very likely, on the other hand, that the number of three-plow and four-plow tractors will increase on the farms that are large enough to justify a power unit of this size.

Operator

The mechanical knowledge and aptitude of the operator are important factors in the efficient use of the tractor. With a little practice almost any one can learn how to drive a tractor. A good tractor operator, however, is more than a mere driver. He understands that any mechanical device needs attention, and that all moving parts must be constantly and properly lubricated if excessive wear and early trouble are to be avoided. He is inclined to watch the behavior of his machine very carefully for any signs of improper operation and to prevent trouble by attending to minor disorders as they occur.

Some men are naturally more mechanically inclined than others and they will acquire more rapidly what might be termed "mechanical sense." Such men usually make good operators without any special training for that purpose. They learn by doing. A course of training in the principles involved in the operation of a tractor would be of benefit to any operator. Only 6.7 per cent of all of the owners interviewed in this study had attended a tractor school and only 5.2 per cent had had previous mechanical experience and training. That the mechanical ability and aptitude of most tractor operators is relatively high is indicated by the fact that all of the repair work on 58 per cent of the farms included in this study was done by farm labor, and more than half of it on 82 per cent of the farms.

Perhaps the mechanical ability of the average tractor owner is higher than that of the average farm operator. About one out of 3.8 Minnesota farm operators have a tractor. The tractor is not being used on any particular size of farm or in connection with any particular type of farming. It is used by some farmers and not by others in every county in the state. It is logical, then, to suppose that the farm operator who is interested in mechanics will be the first to replace animal power with mechanical power.

Further evidence of the mechanical aptitude of the tractor owner and of his appreciation of the importance of proper operation is shown by the fact that 87 per cent of all owners interviewed operate the tractor themselves or have it operated by some member of the family. This corresponds with the report of Cavert on Sources of Power on Minnesota Farms.[27] On farms where hired drivers were used they did not do all of the driving. Only 7 per cent of all of the driving was done by hired help. The proportion of driving done by hired help runs relatively high in northwestern Minnesota where it was 12.4 per cent. Only 4.6 per cent and 3.3 per cent of the driving was hired in southwestern and southeastern Minnesota, respectively.

Table 41

Age of Tractor Drivers on Farms Studied

Age, years	Percentage of drivers
Under 20	14
20 to 29	34
30 to 39	24
40 to 49	18
50 and over	10

Table 41 shows the percentage of tractor drivers on the farms studied in various age groups. The largest percentage of drivers is included in the group ranging from 20 to 29 years of age. It is apparent from these data that, in the main, young men are operating the tractors. Many men of middle age do not take readily to such marked changes as driving a tractor instead of horses. The younger men, however, will learn to operate the tractor just as readily as farmers in the past learned to drive and care for horses. These men as they grow older will be experienced in handling both horses and tractors, and will have no reasons for preferring horses. As the

[27] Cavert, W. L. Sources of Power on Minnesota Farms. Minn. Agr. Expt. Sta. Bull. 262, page 52. 1930.

length of time tractors are used on farms increases, the average age of tractor drivers will doubtless increase also. The average age of all drivers included in this survey was 32 years.

Special Tractor Equipment

The tractor, like the automobile, is constantly being improved and the newer tractors come more fully equipped with accessories as regular equipment than did the older ones. Many of these accessories, such as the air cleaner and oil filter, become a part of the tractor as it is assembled, and the purchaser gets his tractor fully equipped. Some special equipment, however, remains optional with the purchaser.

Extension rims, skid rings, and lugs.—When a tractor is purchased spade lugs are usually supplied. A wheel-type tractor can not be used for farm work without lugs. Skid rings for the front wheels are also part of the regular equipment on most tractors.

Under ordinary conditions it is possible to obtain fairly good results from the average tractor without the use of extension rims on the drive wheels. During certain seasons of the year, however, conditions of soil moisture on most farms are such that extension rims are desirable and sometimes even necessary. They insure a wider range of usefulness for the tractor and make this form of power more dependable. A set of six-inch extension rims may be purchased for from $12 to $20, depending on the size of the wheel and on the weight of the tractor. From $5.00 to $10 must be added for lugs for the extension rims. The additional dependability and usefulness given by the use of this extra equipment is usually sufficient to warrant the necessary expense.

It is more convenient to operate without extension rims when that is possible. Some time is required to put them on and to remove them. If one of the drive wheels is run in the furrow when plowing, it is usually much more satisfactory not to have an extension rim on the furrow wheel. The average width of the regular drive wheel is about 12 inches. The regular extension rim adds 6 inches to this width and the average furrow is only 14 inches wide.

It has been shown that the tractor has displaced an average of 3.2 horses on each of the farms included in the survey. In answering the question as to why more horses were not disposed of when the tractor was added, many owners stated that all the horses that had been retained were not absolutely needed, but some were kept to use in cases of emergency when it was difficult to use the tractor because of wet ground.

All farmers interviewed were asked what they considered the chief disadvantage of the tractor. The largest number answering this question stated that wet and soft ground was the chief disadvantage. The number raising this objection constituted 10.8 per cent of the total. The chief difficulties in operating the tractor were also called for. Fifty-one operators, or 16 per cent of those answering this question, placed wet and soft ground at the top of the list. This difficulty was the one most frequently reported. Nine of these 51 were in the southeast territory, 25 in the southwest, and 17 in the northwest.

Extension rims with spade lugs for the drive wheels greatly facilitate the operation of the tractor when ground conditions are such that it is difficult to obtain sufficient traction with regular wheel equipment or when operating on soft ground. In some cases the front wheels, also, may be equipped with extension rims, and skid rings are provided to facilitate turning where conditions are such that the front wheels tend to skid straight forward when turning is attempted.

Only 16 per cent of all tractors were equipped with extension rims. None of the tractors in southeastern Minnesota were so equipped, 17 per cent of those in southwestern Minnesota had this equipment, and 12 per cent of those in the northwestern part of the state.

For special conditions such as peat land or soft wet ground, two sets of six-inch rims are sometimes used, or special extension rims that are wider than regular.

Power take-off attachment.—The power take-off shaft makes possible the transmission of power in the form of rotoary motion from the engine of the tractor to the machine that is being drawn by the tractor. Most tractors on the market at present are designed in such a way that a power take-off shaft may be attached. This form of power is becoming increasingly more important as more machines are designed to take advantage of it. It allows the transmission of power to the working parts of the machine without the losses that are usually encountered when this power is obtained through drive wheels from the ground.

Many farm machines that are designed especially for tractor use require power to be delivered from the power take-off. Examples are the tractor binder, mower, manure spreader, and potato digger.

The power take-off shaft is not regular equipment with most tractors. It should be part of the equipment when a new tractor is purchased unless the tractor is to be used only for some special purpose for which the power take-off is not required. A tractor that is used for a variety of operations on a general farm must have a power take-off if it is to be used to best advantage.

Safety devices in tractor hitches.—As mechanical power is substituted for animal power it becomes important to place a safety link between the power unit and the implement that is being drawn. When an implement drawn by animal power strikes a stone or other obstruction which causes it to stop instantly, or which causes a sudden increase in the draft requirement, the danger of a break usually is not so great as with a tractor. The tractor ordinarily travels at higher speeds than horses. It, therefore,[28] becomes increasingly important to protect plows and other implements with a weak link in the hitch as tractor power becomes more common and higher speeds more prevalent.

The wooden break pin is the safety device in most common use. It was used on 136 of the 314 tractors included in this study. There are several disadvantages to using wooden break pins as a means of preventing breakage in machinery due to sudden stops. In tests made at the California Agricultural Experiment Station, it was found that the strength of wooden break pins of the same size and made of the same material varied a great deal.[29] Frequently the strongest pin in a lot of a dozen that were tested would carry twice the load that would break the weakest.

Tests were also made to compare metal pins with wooden pins to determine their characteristics. The breaking strength of metal pins is much more uniform than those of wooden ones. A common machine bolt one-fourth inch in diameter will satisfactorily replace an oak pin three-fourths inch in diameter. A three-eighths inch machine bolt is approximately equivalent to a one-inch pin made of oak. Carriage bolts of equal size will stand somewhat less than machine bolts and soft steel rivets slightly less than carriage bolts. The operator is warned not to use bolts salvaged from machines, automobiles, trucks, tractors, and other high-class equipment. If metal break pins are used instead of wooden ones it is advisable to drill a new hole into the drawbar that is nearer the size of the metal pin than the hole intended for a wooden pin.

A type of safety link that is coming into more general use is the spring overload release hitch. Most hitches of this type are so designed that they may be made to release at any desired pull. A spring that absorbs some of the small variations in draft is included in the construction of most types.

Such a hitch has the advantage over break pins that it may be set to release at a given pull and the variation in the pull required to effect the release is relatively small. On the other hand, it is more expensive and requires some adjustment from time to time. Such hitches were found in use on 20 per cent of the tractors studied.

Automatic steering devices.—Self-guiding devices were found on 11 per cent of the tractors studied. No detailed information was obtained with regard to the satisfaction they were giving.

[28] The forces which are developed when a heavy object stops suddenly tend to increase as the square of the velocity.

[29] Hoffman, A. H., and McKibben, E. G. Substitutes for Wooden Break Pins. California Agr. Expt. Sta. Bull. 482. 1929.

Practically all of the self-guiding devices are designed for use when plowing. They can not be used satisfactorily for other operations. The guiding is accomplished by a shoe on the end of an arm running in the furrow that was made the previous round. Guiding devices may be divided into two general groups. One type is entirely automatic and will guide the tractor without the presence of the operator. The plowing must be done around the field instead of in lands if such a device is to be used. It is further evident that stones and stumps that might throw the plow out of the ground would interfere with the guide shoe the next time around. The guide is usually so constructed that the tractor engine will automatically be shut off whenever such interferences occur.

Another type of guide may be used for plowing in lands as well as for plowing around the field. This type requires the attention of the operator at the end of the furrow while turning. While the operator is relieved of the constant strain of guiding the tractor while plowing is actually being done, he can not go off and leave the tractor operating alone.

Special Machinery

The tractor, in itself, constitutes a source of power which can not be utilized except by means of additional equipment. The average tractor owner has a certain amount of equipment suited for horse work. Some horse-drawn machinery may be used satisfactorily with the tractor while others may not be.

Table 37 shows the kind and cost of special tractor machinery purchased on the farms included in this study. A tractor plow is usually purchased with the tractor. A horse plow is not suitable for use with tractor power. A tractor disk harrow is found on most tractor farms, altho horse disks are used occasionally. Frequently such horse-drawn equipment as the spring-tooth harrow and grain binder are used with tractor power.

Manufacturers of farm equipment are placing on the market many machines that are designed especially for use with tractor power. With such equipment it is possible, as a rule, to utilize tractor power more advantageously than with the use of horse equipment. The binder furnishes a good example. Table 18 shows that the power cost per acre is 32 cents when a two-plow tractor is used on a seven-foot binder as compared with 29 cents per acre when an eight-foot binder is used, and 24 cents per acre when using the ten-foot tractor binder operated with the power take-off. This is true in spite of the fact that the fuel consumption per hour of the two-plow tractor for these operations is 1.54, 1.64, and 1.85 gallons for the seven-, eight-, and ten-foot cut, respectively. The additional capacity of the larger machines more than offsets the slightly higher fuel consumption.

In making this comparison, attention should be called to the fact that two men are required to operate the horse binders with the tractor; one man is needed on the tractor and another on the binder. The tractor binder, on the other hand, may be and usually is operated by one man only, altho occasionally two men are used.

Important advantages in using regular tractor equipment are in the fact that the tractor is then used more nearly to its optimum capacity, thus reducing the cost per unit of work performed. Uusually such equipment is so designed that less labor is required for its operation. This is because adjustments are more accessible and more easily made.

A farmer who is purchasing a tractor and perhaps disposing of some horses must make some change in the supply of his equipment. To what extent he is justified in supplying himself with machines designed for tractor use will depend on several factors. If some of the horse-drawn machinery is relatively new and is of such capacity as to utilize the tractor power to good advantage, he may be justified in using it. It is doubtless true, on the other hand, that the savings effected in cost of operation with tractor equipment over the cost of doing this work with makeshift horse-drawn equipment will in many cases more than offset the additional cost of new equipment in a very short time. With the rapid changes now taking place and which have taken place during the last few years in design of machinery, the wearing out and disuse of machines probably will become a more important factor with farmers than it has been in the past.

Co-operative purchases by two or more farmers offer a means of obtaining the advantages of equipment that is not used much on any one farm or that may be too high in price to justify its use on a small farm. Twenty-four per cent of the farmers interviewed owned one or more machines in co-operation with their neighbors.

With a larger variety and a more highly specialized line of machinery to choose from, the farmer must exercise more care in the selection of his equipment. While one machine may be very profitable on his particular farm, another machine may not add anything to the net income and may even be a disadvantage. The farmer who is going to have his equipment pay him dividends rather than tax him for owning it, must exercise some care and study in its selection and use.

Most Efficient Tractor Load

All of the energy supplied by the tractor engine is never available at the drawbar, the power take-off shaft, or the belt. A certain amount of the power is lost when it is transmitted through the parts of the tractor, and in the case of drawbar work, some of the power is consumed in moving the tractor itself. The amount of power required for propelling the tractor is the same regardless of the total amount of power being developed; therefore the proportion of the total amount of power developed, that is available for work at the drawbar, increases as the load increases. The limit of this increase is the total capacity of the tractor for doing drawbar work. Usually the most efficient results are obtained when a tractor is operating at slightly less than the upper limit of its capacity.

The group of tractor costs which are called fixed charges, including depreciation and interest, are affected very little, if at all, by the proportion of its maximum capacity, at which the tractor is operating. Table 16 shows that the fixed charge is 40 cents per hour for the average three-plow tractor. This charge would be the same whether the tractor was developing 15 or only 6 horse power. Therefore, the fixed charges per horse-power hour are much lower when the tractor is developing its maximum power.

The easiest way to obtain the most efficient load for a tractor, from a theoretical standpoint, is to supply a machine that is large enough to utilize most of its capacity. According to data obtained by the Montana Agricultural Experiment Station[30] the optimum load for Montana conditions for the average three-plow tractor is about 15 or 16 feet of tandem disk harrow, about 30 feet of grain drill, about 35 feet of smoothing harrow, and about three 14-inch plow bottoms. This method of obtaining economical tractor operation and low power costs may be used under some conditions but is not practical generally in Minnesota. The average Minnesota farm is not sufficiently large to justify equipment in units large enough to load the ordinary farm tractor most efficiently. This may be done for some operations such as plowing and perhaps disking, but it is out of the question on many others.

Table 42

Combinations of Implements in Use on Farms Studied

Combination	Number of farms			
	Southeast	Southwest	Northwest	All areas
Plow and harrow	18	13	25	56
Disk and harrow	11	21	8	40
Spring-tooth harrow and harrow	21	3	8	32

Another method of obtaining a most efficient tractor load, and a more practical one for conditions in the greater part of Minnesota, is to hitch two or more kinds of implements behind the tractor at the same time. Several combinations were used on farms included in this study.

[30] Murdock, H. E. Mechanical Tests on Tractor Farming Equipment. Mont. Agr. Expt. Sta. Bull. 243, p. 19. 1931.

These are shown in Table 42. The combination of the plow and harrow appears to be the most popular. This combination is reported in use with 56 of the 314 tractors. The disk and harrow combination is used with 40 tractors, and spring-tooth and spike-tooth harrows with 32 tractors.

There is no close correlation between the number of combinations used and the location. The highest number (50) reporting combinations is in southeastern Minnesota. There were 41 in northwestern Minnesota and 37 in the southwest.

In the southeastern part of the state the spring-tooth harrow and harrow combination is most popular, 21 reporting its use. The disk and harrow combination leads in the southwestern part, with 21 reporting it, and in the northwestern part the combination of plow and harrow takes the lead, 25 reporting its use.

Pulling two or more implements with the tractor at the same time is a method that is not in use to the extent that it might be. Other combinations of implements than those reported here have been used satisfactorily. Wherever this method is used it is a more or less makeshift arrangement on the part of the operator. The standard tractor machines have not been designed with this in view. As a result, makeshift and in some cases unsatisfactory hitch arrangements must be made to accommodate the two implements. If special hitch arrangements were incorporated in the design of some of the implements that might be used in combination with others, it would go a long way toward encouraging this practice.

Maximum Daily Performance

Another characteristic of tractor power that differentiates it from animal power and that is very important for the operator to recognize and to take advantage of, is the fact that the tractor may be operated continuously for long periods of time. An illustration of the possibilities in this direction is furnished by a test conducted by the University of California during which a tractor engine was run 408 hours without a stop.[31] During this period the tractor chassis was run 384 hours and the rest of the time was used for servicing the tractor and implements, for making tractor adjustments, and for reading testing instruments.

Table 43 shows the number of tractors on which drivers were shifted during the course of the day and the number used for night work. Drivers were shifted on 14 per cent of all tractors and the same percentage was used for some night work. Doubtless most of the tractors

[31] Hoffman, A. H. and Stirniman, E. J. A Field Test of Tractor Wear and Endurance. Agricultural Engineering, Vol. 10, No. 1, p. 35. Jan. 1929.

included in one of the groups are also included in the other, which means that in the main the shift of drivers occurs on the same tractors that are used for night work.

Table 43

Number of Tractors Operated Longer Than the Normal Work Day

		Southeast	Southwest	Northwest	All areas
Shift drivers	Number of tractors	10	14	18	42
	Per cent	10	16	18	14
Night work	Number of tractors	11	9	20	40
	Per cent	10	10	20	14
	Hours per year, per farm reporting	21	20	63	42

The night work is not very important in southeastern or southwestern Minnesota. Only 10 per cent of the tractors in each locality were used for night work and the average number of hours per farm per year is small. Tractor operation during the night becomes relatively more important in northwestern Minnesota where 20 per cent of the operators did an average of 63 hours each per year of night work. This is doubtless due to the larger farms and the type of farming in that section, with the consequent fact that more work of a given kind must be done at a certain season of the year.

In Table 44 the number of hours per day that the tractor is worked is compared with the number of hours per day that horses were used on the same farms. Only 3 per cent of those reporting stated that the tractor was used fewer hours than horses. Forty per cent stated that there was no difference and 57 per cent reported longer days in the field with the tractor. It is evident that many farmers are taking advantage of the possibilities of operating more hours per day. The operators who furnished the data in Table 44 reported 8.6 hours per day when horses are used. The average with the tractor was 9.5 hours, an increase in the length of the field day of 0.9 hour or 10.5 per cent.

Table 44

Comparison of Number of Hours per Day That Horses and Tractors Are Worked

Length of tractor day	Farms	
	Number	Per cent
Shorter than with horses	7	3
Same as with horses	111	40
One hour longer	75	27
Two hours longer	63	22
More than two hours longer	24	8

GENERAL EXPERIENCE AND OPINIONS OF THE TRACTOR OWNERS

Each tractor operator interviewed was asked questions bearing on the satisfaction his tractor was giving. These questions had to do with some of the more general relationships of the tractor to farm operation. The summarized answers reveal some interesting and important facts.

Servicing and Repairing the Farm Tractor

The possibility of obtaining adequate service is coming to be a very important factor in the selection and purchase of farm equipment. No mechanical device will continue to operate perfectly for an indefinite period of time without attention. As some of the working parts become worn, they need to be replaced or adjustments must be made that will compensate for the wear. Parts become loose and breakages occur on any machine that is in continuous use.

A tractor is of use to its owner only when it is in operation and performing some useful work. It is highly important that the tractor be in operation at certain periods of the year and under certain circumstances, if it is being depended upon as a source of farm power. When breaks occur during the midst of the harvest season, for instance, it may mean the loss of a considerable sum of money through loss or damage of the crop if operations can not be kept going. It is then that the tractor operator must have immediate and satisfactory service. This factor becomes increasingly important as mechanical power and machinery are being depended upon more largely.

Eighty-seven per cent of all of the tractor owners stated that service for their tractors was available at a local dealer. The average distance from the farm to the point of service was 6.2 miles. This distance is not very great when one considers that the telephone and automobile are available on most farms.

A more important factor than distance is the ability of the local dealer to give satisfactory service. To be able to service equipment properly the dealer must have a sufficient supply and variety of repair parts on hand and must have a thoro knowledge of the machines that he sells so he may intelligently and efficiently analyze the trouble and remedy it. Ten per cent of the owners that reported on the service obtainable stated that it was unsatisfactory. The other 90 per cent were able to secure satisfactory service.

Most of the repairing on tractors is done during the slack season. Usually only emergency repairs are done during the busy season and these are seldom large. The larger important jobs, such as grinding valves, reboring cylinders, and replacing pistons, may ordinarily be deferred to an opportune time.

Most of the tractor owners interviewed did most of their own repairing. Only 5 per cent reported hiring all their repair work. Eighty-two per cent did more than half of their own repairing. Fifty-eight per cent did all of their own repair work. When the home repair work on all of the farms is taken into consideration it is found that 84 per cent of all of the repairing was done on the farm.

Table 45 summarizes the items of repair reported as being performed on the farm by farm labor. Almost half of the items are on the engine proper, valve grinding being by far the most important item in the group. Sixteen different items were mentioned that would normally come under this heading. The ignition group is next in importance. The items constituting this group have to do with spark plugs, timer, and other parts of the ignition system. The necessity for attention to spark plugs is mentioned more often than any of the other items. Under transmission, difficulties with gears and clutches principally are mentioned. This group is much less prominent than the preceding two groups. Carburetion includes mainly carburetor troubles and adjustments and some mention is made of trouble with the gasoline tube through which fuel is conducted from the tank to the carburetor. Miscellaneous items are numerous, but individually they are of relatively little importance.

Table 45

Tractor Repair Work Done by Farm Labor

Items	Number of farms reporting				Percentage of total
	Southeast	Southwest	Northwest	All areas	
Engine	..	..	..	..	47.8
Valves	18	19	48	85	...
Bearings	7	11	10	28	...
Piston rings	4	9	2	15	...
Connecting rods	2	4	1	7	...
Other	3	16	14	33	...
Ignition	29	22	52	103	29.2
Transmission	4	15	9	28	7.9
Carburetion	5	9	6	20	5.7
Miscellaneous	5	14	4	33	9.4

In reviewing these items it is noted that many of them consist of adjustments that must be made on every motor and that the operator should be expected to make. Other items, such as grinding valves, are regular jobs on any motor but are not always performed by the operator. Such items as taking up bearings and replacing piston rings are probably more often done by expert labor than by farm labor. Such jobs need not be done more than once each year on the average tractor.

Table 46 shows the number of tractors that were out of service for various periods when there was work to be done. A loss of tractor time from this cause was reported on 85 farms, almost one-third of the total. Two-thirds of the tractor owners apparently had not been handicapped in this respect. While the average length of time that the 85 tractors were out of service when there was tractor work to be done was 2.9 days, Table 46 indicates that 45 per cent were laid up for less than two days and that 29 per cent were laid up for from 2 to 3 days. The percentage of tractors studied that were out of service for 4 days or longer is relatively insignificant.

Table 46

Variation in Number of Days Time Lost Annually by Operators Because Tractor Was Out of Service

Time lost, days	Number of operators			
	Southeast	Southwest	Northwest	All areas
Less than 2	15	9	14	38
2 to 3	5	9	11	25
4 to 5	1	2	4	7
6 to 7	1	2	4	7
8 to 9	0	0	1	1
10 and more	2	3	2	7

The reasons given for the lost time are numerous and varied. In the main they constitute breakages that seldom occur but are likely to occur at any time. Occasionally, however, replacing piston rings and grinding valves were given. These ordinarily can not be classified as emergency repair jobs because the wise operator usually plans to do such work when there is no tractor work to be done. These data indicate that while the tractor is not 100 per cent reliable, yet it possesses a relatively high degree of reliability. Only 7 per cent of the tractors studied were delayed 4 days or more because of breakdowns when there was tractor work to be done; 71 per cent experienced no such delays.

Necessary delays in tractor operation will doubtless decrease as time goes on, because tractors, like automobiles, are gradually being built better. Factors other than quality of materials, design, and construction contribute to such delays, however. Among these are the availability of repair parts and the mechanical aptitude of the operator. It is significant that 5 of the 85 operators were delayed because they were obliged to wait for repair parts. The care and judgment of the operator in driving his tractor often go a long way toward warding off costly delays.

Miscellaneous Considerations Affecting Preference for Horses or Tractor

On most farms where tractors are used there is an abundant supply of horses. On many farms, in fact, there are sufficient horses to do much of the work that a tractor could do. It, therefore, becomes a matter of being able to choose either horses or the tractor for doing such work as harrowing, seeding, or cultivating.

All farmers interviewed were asked to name the operations for which they preferred to use horses and were also asked to name the operations for which the tractor was preferred. The answers are given in tabulated form in Table 47. Tractors are preferred principally for the heavy field work. For operations that require special hitches if the tractor is to be used, horses are usually preferred. The general-purpose tractor had been sold to a very limited extent when this survey was taken. It is designed especially to perform many of the operations for which horses are commonly used in preference to the standard type of tractor. In addition, the general purpose tractor performs the heavy field work just as well as the standard tractor does. It appears, therefore, that this type of tractor should be better able to replace animal power on the average farm than the standard tractor.

Table 47

Tractor or Horse Preference for Certain Farm Operations

Operation	Per cent of farms	Operation	Per cent of farms
	Tractor preferred		Horses preferred
Plowing	76.5	Seeding	48.4
Spring-tooth harrowing	28.4	Cultivating	47.5
Disking	23.2	Harrowing	35.4
Cutting grain	17.5	Cutting grain	20.7

To obtain some information with regard to the extent to which animal power and tractor power duplicate each other, the farmers were asked whether their horses were idle while the tractor was doing work that horses could do. Answers were received from 230 farmers. Fifty-nine per cent stated that their horses were doing nothing while the tractor was doing work that could have been done with horses, also that their horses were thus idle an average of about 15 days per farm per year.

The reasons for using the tractor instead of horses are shown in tabular form in Table 48. Most operators are impressed with the fact that the tractor works faster than horses. To a certain extent this objection to the use of horses as well as the objection that sufficient men are not available to drive them may be overcome by hitching them in larger units. These large units are out of the question on a relatively small farm because the cost of keeping the additional horses would more than offset the value of labor saved by the use of large teams. On the other hand, the rate of travel of the tractor is normally faster than that of horses and the tractor may be operated continuously for a longer time than horses. The fact that heat and flies do not affect the tractor is considered second in importance by those answering this question. Forty-one per cent of the farmers who answered this question stated that their horses were not idle while the tractor was doing horse work. This is a necessary condition if the available power on the farm is to be used to best advantage.

Table 48

Reasons for Using the Tractor in Preference to Horses When Both Are Available

Reasons	Number of farms				
	Southeast	Southwest	Northwest	All areas	Per cent
Tractor works faster	24	15	17	56	41.0
Heat and flies do not affect tractor	6	14	15	35	26.0
Sufficient men not available to use horses	21	7	3	31	23.0
Tractor does better work	7	5	2	14	10.0

Another factor that might contribute to a preference for either horses or tractor is the opinion of the farmer as to which is more dangerous to use. Nine per cent of those expressing their opinion stated that the tractor was more dangerous than horses while the remaining 91 per cent stated that horses were more dangerous. It is apparent, therefore, that the average tractor operator considers his possibilities of getting hurt much less when he drives a tractor than when he uses horses. Twenty operators out of 290 stated that they had been hurt by the tractor; 270 stated that they had never been hurt.

Some Advantages and Difficulties in Tractor Operation

An attempt was made to obtain the opinions of tractor owners concerning the advantages and disadvantages of tractor power, from experience. Each farmer was asked the advantages of the tractor and the chief difficulties encountered in tractor operation. The answers and the relative importance of each are shown in Table 49. The importance of being able to do work faster than with horses is again emphasized by a large majority. There is not much difference in the relative importance of the other advantages.

The only important difficulties are: wet and soft ground, ignition troubles, and hard starting. There is not much difference in the relative importance.

The remaining difficulties are mentioned by so small a percentage that they are insignificant. Of the first three, only one has to do with conditions outside the tractor itself. Eight of the ten items under difficulties are mechanical. In the main, these represent conditions over which the operator has little control. It is true that the operator who gives his tractor the proper attention will experience fewer mechanical difficulties than the careless operator. It is also true that as tractor design and construction is improved there is less possibility of difficulty with most of the items mentioned.

In addition to ascertaining the difficulties encountered by these farmers in actually operating their tractors, data were also obtained as to what they considered the disadvantages of owning a tractor. Only two were mentioned in reply to this question. Thirty-four operators gave wet, soft ground as a disadvantage and 21 stated that the tractor was too expensive.

Table 49

Advantages and Difficulties in Tractor Operation

Advantages	Number of farms	Difficulties	Number of farms
Faster work	186	Wet and soft ground	51
Belt power available	52	Ignition troubles	48
Better work	37	Hard starting	41
Saving of man labor	36	Carburetor	10
Suitability for plowing	33	Clutch	7
Freedom from effect of heat and flies	19	Inexperience of operators	6
		Oiling system	5
		Transmission	5
		Valve trouble	4
		Bearings	3

Two hundred sixty owners, or 91 per cent of those answering, considered their tractor a profitable investment; 9 per cent did not. These answers in the main were not based on any studied analysis but represented their opinions.

Ninety-five per cent of the owners stated that they intended to purchase another tractor when their present machine had to be replaced. The other 5 per cent stated that their present tractor would not be replaced by another. Apparently a majority of present tractor owners are convinced, as a result of experience, that for them the tractor is a profitable investment.

CHARACTERISTICS OF TRACTOR POWER

The tractor as a source of farm power has certain characteristics that must be recognized by the operator if it is to be used to best advantage. The tractor usually is purchased primarily to perform work formerly done with horses. The new tractor is usually considered a substitute for horses in drawbar work. The tractor makes it possible to do much more belt work than was done before. Because tractor power is different from animal power it is necessary to make changes not only in equipment, but also in the method of performing certain operations and in the operations themselves, if the most benefit is to be derived from this form of power.

It is difficult to group these characteristics as either advantages or disadvantages. Whether a certain one is advantageous or detrimental to a particular operator, depends on conditions, such as size of farm, type of farming, and the operation in question. As an illustration, the fact that a tractor is a relatively large power unit that can not be divided into smaller units is an advantage for plowing but probably is a disadvantage for mowing on the same farm. Some of the most important characteristics of tractor power that distinguish it from other forms of farm power will be discussed briefly.

The Tractor Is a Relatively Large Power Unit

For performing drawbar work the average tractor is equivalent to 8 or 10 horses. If a farmer has 10 horses he does not drive a 10-horse team every time he does horse work. In effect, that is what happens every time a man takes out the tractor. He can not do as he had been accustomed to doing with horses, namely, adjust the size of the power unit to the load. When tractor power is used, the size of the unit is fixed and the load must be adjusted to it.

This characteristic of tractor power is an advantage when the time and amount of work required to get 10 horses ready and hitch them up is compared with the average daily time required to get the tractor under way. Tractor power lends itself more readily to the control of a large power unit by one man than does animal power.

On the other hand, if the power and labor cost per unit of work done with the tractor is to be kept as low as possible, it is necessary to operate the tractor as near to its capacity as possible. On many farms it would be out of the question to use units of such machines as the smoothing harrow and grain drill of sufficient size that the full capacity of the tractor would be utilized when performing one operation only. It, therefore, becomes advisable to hitch more than one implement to the tractor at the same time and perform two or more operations simultaneously. Examples of such possible combinations are disking and harrowing, seeding and harrowing, and seeding and rolling.

Horse-drawn implements are frequently used with the tractor. Seldom economical operation is possible with such horse-drawn equipment as the disk harrow, grain drill, or grain binder. Machinery that is designed especially for tractor use is usually of such size and design that more economical use of tractor power is possible, hence lower cost per unit of work done than with equipment designed for horses.

Relatively Large Quantities of Belt Power Available

The amount of power available at the tractor pulley is always larger than that available at the drawbar. Power generated in the engine of the tractor needs to be transmitted only a short distance and by means of very little mechanism before it is available at the pulley. Because of this there is little possibility for loss of power through friction on its way from the crankshaft of the engine to the belt pulley.

Before drawbar power can become available, however, the power must be transmitted from the engine to the tractor drive wheels. Because this transmission must be more elaborate than the transmission to the belt pulley, the losses due to friction are higher when power is transmitted to the drive wheels. Drawbar power is available only when the tractor itself is moving forward. It consumes a relatively large portion of the power generated by the engine. The power that remains after losses due to friction are deducted, together with power required to propel the tractor itself and losses due to slippage, is available for such work as plowing and disking. In most tractors the available drawbar power is from 50 to 75 per cent of the power at the belt pulley.

When a tractor is added to the farm equipment, it brings with it a relatively large amount of potential belt power. The purchaser must take the belt power if he wants the drawbar power. The amount of belt power available is usually much larger than before the tractor was purchased. Since the cost per hour of operating the tractor becomes less as the number of hours use per year increases, the operator must recognize the possibilities of using the tractor for belt power as well as for drawbar power. Such work as grinding feed, filling silo, and sawing wood, formerly done by custom power, is performed by the farmer's own power after he has the tractor. Frequently the tractor owner is able to do considerable custom work with his tractor and thus reduce the power costs of performing his own farm work. The possibility of doing custom work, however, decreases as the number of tractors in a community increases.

Tractor Power Applied Directly to Drawn Implements by Means of the Power Take-Off

Many characteristics of tractor power make it very different from animal power, thus necessitating changes in practices on the part of the operator. While animals are capable of furnishing power only in drawbar form, the tractor is capable of supplying it in three different forms—drawbar, belt, and take-off. This gives tractor power an advantage over animal power, especially when the operator is equipped to take full advantage of power in the different forms offered.

When a binder, mower, or potato digger is drawn with horses, power to operate the machine is obtained through the drive wheels making contact with the ground. The power take-off shaft on a tractor provides a means for transmitting power from the tractor engine directly to the machine being drawn. On a grain binder, for instance, the cutting and binding mechanism may be operated whether the tractor is moving forward or not, and is operated at constant speed regardless of the speed at which the tractor moves forward. The force applied at the drawbar then need only be sufficient to move the machine through the field.

This method of operating machinery drawn by tractor is more economical from the standpoint of the use of power than obtaining power through the drive wheels of the machine. In the latter case there are many possibilities for losses due to slippage and poor traction, on the part of both the power unit and the machine. In the last few years many standard machines, such as the grain binder, mower, manure spreader, corn picker, and potato digger, have been designed and are being built in such a way that tractor power may be utilized to best advantage. Machines mentioned that are designed especially for tractor use are operated with the power take-off. In many cases the capacity of the machine has been increased so that a larger percentage of the available tractor power might be utilized.

Continuous Use for Long Periods Possible

The average full day for horses is from eight to ten hours. The tractor may be operated continuously for relatively long periods of time, if it is supplied with fuel and lubricants at regular intervals. This characteristic of tractor power is one of which many operators do not take advantage. Most tractors may be equipped with lights so that they may be operated at night as well as in the day. While some farm operations do not lend themselves to night work, many operations can be performed just as well at night as in the day. The possibility of using tractor power in this way is a distinct advantage during certain seasons of the year when considerable field work is to be done, such as planting and harvesting within specified times. Frequently the periods for doing such work are not very long. By shifting drivers the tractor may often be operated almost continuously during such critical periods. The rate of performance with the tractor is not affected by hot, sultry weather or the presence of flies and other insects.

These are some of the most important characteristics of tractor power that distinguish it from animal power. It is impossible to make general recommendations for using tractor power that will apply to all farms or to a number of farms. It is necessary for the operator to recognize and study the ways in which tractor power is different and then must arrange his equipment, his farm operations, and the methods of performing them in such a way that the tractor power will serve him best.

USING TRACTOR POWER TO BEST ADVANTAGE

Mechanical Considerations

One hundred tractors of a given make, size, and model are as nearly alike as it is humanly possible to make them. If each of such a group of tractors were given to each of 100 operators it would soon be found that differences would appear in the way in which they perform. Breakages would occur on some that would not occur on others. After several years it would be found that the cost of repairs would be higher on some than on others. In fact, the useful life of some of these tractors would be very much longer than that of others.

Doubtless defective materials and poor workmanship in the construction of the tractors would be responsible for some of these differences. Differences due to these causes, however, are bound to be very small because of the high degree of standardization in the manufacture of machinery. The most important factors contributing to differences in tractor performance are the care and intelligence with which the operator handles his tractor.

The farm tractor is a highly developed group of inter-related moving parts. The relationship of these parts to each other and the precision and accuracy with which they move and with which each performs its particular function have been improved upon from time to time so that the tractor operator today need have relatively little knowledge of the principles of gas engine operation or of machinery construction in order to run his tractor successfully and keep it going in a reasonably good condition.

However, the tractor is an inanimate object and it requires the attention that must be given to every mechanical device in operation. All moving parts must be kept lubricated. Some parts will show wear after a time and must be adjusted or replaced. Breakages are bound to occur and must be given prompt and proper attention. The degree of intelligence and diligence with which the operator pays attention to these mechanical requirements will to a large extent determine how long and how successfully he will use his tractor.

At least once each year, preferably during the slack season, it is advisable to make a thoro study of the mechanical condition of the tractor and make any necessary repairs. Frequently the operator does such work himself; occasionally an expert mechanic is hired.

It is important that such work be done by someone who is thoroly familiar with the mechanical principles of tractor operation and who is familiar enough with the various parts to know when and what kind of repair work is necessary. Such jobs as grinding valves, taking up main or connecting rod bearings, reboring cylinders, fitting pistons, and replacing worn gears should be included in this annual repair job if they need to be done.

The most successful operator, so far as the mechanics of the tractor is concerned, is the one who appreciates the necessity for keeping all working parts well lubricated and who anticipates the necessity for repairs and adjustments from time to time. He can, in many cases, eliminate causes of trouble before serious trouble occurs, and thus eliminate delays during rush seasons and keep down the repair cost.

Economic Considerations

Several economic factors should be carefully evaluated by a farmer considering the purchase of a tractor. In order to use it advantageously, he must so organize his business that the use of tractor power will either decrease the cost of operation without a corresponding decrease in income or else will increase his income more than it increases his operating expense, or, better still, do both. Operating costs may be reduced by displacing horses and reducing the cost of the horses retained. The amount of man labor needed to operate the farm may be reduced in two ways by the use of a tractor—given operations may be speeded up and thus reduce the man labor used directly; also it can be done at a time when they can be done with the least effort. If the labor saved is that of the farmer or members of his family, such saving may not reduce the expenses but merely lighten the work. Likewise, unless the reduction is sufficient to reduce the amount of labor hired, the net effect will be to shorten the working day rather than reduce expenses. This is especially likely to be true in case of men hired by the year or season. If other productive work can be done with the labor saved, the income of the farm may be increased even if costs are not reduced.

A further possible saving in farm expense may be effected by using the tractor for belt operations. Many farmers pay out considerable money either for the rent of power for threshing, silo filling, corn shredding, feed grinding, and wood sawing, or for custom work of this type. The farmer may be able not only to do this work with his own tractor at less than rental or custom rates, but able to do the work at the time that fits best into his labor program.

In considering the possible reduction in costs by the use of tractor power, the farmer must keep in mind that in order to use the tractor effectively he must purchase machinery designed especially for it.

Some of the horse machinery must be retained to use with the horses retained and in most cases the resale value of used farm machinery is so low that they can not be sold for a sufficient sum to offset to any considerable extent the cost of the tractor machinery that must be bought. In order to use the tractor for belt work, much, if not all, the machinery needed must be purchased. Even if co-operation with neighbors is practiced in the purchase of belt machinery, this added investment is merely reduced and not eliminated. In most cases, the total investment in power and machinery is greater after the purchase of a tractor than was required for the operation of the same farm with horses. Furthermore, the purchase of the tractor and the machinery to use with it as well as the purchase of tractor fuel, oil, and repair parts require cash outlay. The horses may be reared on the farm, fed farm-raised feeds, and cared for by family labor with very little direct cash cost. This is an especially important consideration in case of the farmer who is already heavily in debt, or in times of low prices for farm products.

In addition to the effect of the tractor on operating costs, the prospective tractor purchaser must consider the possibility of increased income. Farm income may be increased directly by farming more land or by the use of the tractor for custom work. The work on the home farm may be speeded up sufficiently to allow the farmer to do work on other farms or such non-farm work as road dragging. Indirectly, the farm income may be increased by more thoro preparation of the seedbed and by the more timely performance of the various operations. The prospective tractor purchaser may save himself both disappointment and financial loss if he carefully evaluates the possible effect of the tractor on his operating cost and income before he decides on the purchase or selects the type and size of machine for his particular farm and the equipment to use with it.

The man who already has a tractor must consider the same points in attempting to use his tractor most advantageously. In addition he must give special consideration to the matter of keeping down his cost of operation. One of the most important ways of decreasing the unit cost of tractor operation is to increase the amount of work done by the tractor. On the small farm a limited amount of work may be adapted to the tractor without a considerable investment in special equipment. The work on the home farm may be supplemented by outside work where it is available. The total cost of the tractor increases directly tho not proportionately with an increase in annual use. Unless this increased service, even tho secured at a lower cost per hour, does not increase the farm income or decrease the other costs of operation enough to more than offset its cost, it is of no advantage.

Many tractor owners are using their tractors for so little work that they are unable to make any material reduction in costs of animal or other power. Fifteen per cent of the tractors used in this study were used less than 200 hours annually. The purchase of these tractors has in most cases added to the cost of farm operation without a corresponding increase of income. It should be recognized that once a farmer has purchased a tractor, it may be more economical to use it in a limited way than to permit it to remain idle or to sell it for what it will bring as a used machine. For example, a man may pay $1,200 for a tractor and after two or three years find that he has not sufficient work for it to justify the investment. The resale value may be only $300. As long as the tractor will pay a reasonable return on this $300, it may be more economical to use it for the limited work available than to sell it and return to animal power exclusively. Obviously, it would have been much better if this farmer had considered in advance, in the light of his own experience and any available information on tractors such as is presented in this study, the possibility of the profitable utilization of a tractor on his farm and thereby avoided making an unwise investment. The most important factor in using a tractor to economic advantage is an advance calculation of the possible effect of its use on the expense and income of the farm before deciding to make the purchase and before selecting the size and type to buy.

PRESENT TRENDS IN TYPES OF TRACTORS

It has been shown that the tendency during the last several years has been toward the use of the three-plow tractor and away from the two-plow size; also that the same tendency is shown in the intentions of present tractor owners so far as the future is concerned. The tractor in most common use on Minnesota farms today is the standard four-wheel type, on which the two rear wheels are the drive wheels. This type is suited for such drawbar work as plowing and drawing various types of tillage machines. The tread is such that one front wheel and one of the drive wheels usually go in the furrow when plowing.

Several years ago the general-purpose tractor was placed on the market. It is designed to perform a greater variety of operations than is possible with the standard type. The principal fundamental differences between the general-purpose and the standard types are that the general-purpose has more clearance and has a different tread arrangement, which varies on some makes. These differences in design are prompted by the desire to make the tractor suitable for planting and cultivating row crops. Tractor engineers, however, have gone further than this in the design of the general-purpose tractor. They have kept in mind the necessity for advantageously doing such work as mowing, picking corn, and cutting grain. Special equipment of various kinds is being developed for use with the general-purpose tractor. The operator of an average sized general farm can get along with fewer horses when using a general-purpose tractor than if the standard type is used. With the standard tractor it is necessary to keep a number of horses regardless of whether a tractor is used or not. These horses are required for row-crop work and other operations for which the standard type of tractor can not be used advantageously. By performing a larger number of operations with the tractor the number of horses may be reduced.

The general-purpose tractor is made in the two-plow and the three-plow sizes. It is possible, therefore, for the prospective user to select the size that most nearly fits the size and character of his farming operations. In previous discussions it was shown that the larger tractor is advisable if enough of the operations provide a load that will utilize most of the tractor capacity. If the load most of the time will be of such size that it could be handled by a two-plow size, it is a matter of economy to use the smaller tractor. The cost per hour of operating the larger tractor with no load is higher than that of operating the small one. Most of the leading manufacturers are offering a general-purpose tractor for sale.

Another change is the more general use of the crawler or track-laying type of tractor. This tractor has been used largely for industrial and construction work where the tractor must be operated under a variety of conditions of soil moisture and types of soil and topography. Because the track-laying type can be used under more conditions for drawbar work than can the wheel-type, manufacturers are paying more attention to it and more farmers are demanding it in preference to the wheel type. The price of wheel-type tractors has been less than the track-laying tractors of the same size and capacity. At present the track laying type is available in sizes from the two-plow up, and the general-purpose track-laying type is also available for row-crop work and for other general farm work.

Recently a manufacturer has placed on the market a wheel type tractor in which all four wheels are used as drive wheels. From the standpoint of traction the four-wheel drive type has advantages over the two-wheel drive and perhaps encroaches on the place occupied by the track-laying type in that respect. A successful four-wheel drive tractor is a possibility from an engineering standpoint.

Most farm tractors are equipped with four-cylinder motors. Some have two-cylinder and a few have six-cylinder motors. There has been no definite trend with regard to number of cylinders, altho the number is increasing.

Recent changes and present trends in types and models of tractors indicate that manufacturers are paying considerable attention to the adaptability of the tractor to all kinds of farm work. It is highly important to the prospective purchaser to keep informed with regard to the type of equipment available from time to time. As the variety increases it becomes increasingly difficult to select the best that is available for any particular set of conditions.

SUMMARY

The number of work horses on Minnesota farms decreased 13 per cent during the ten-year period ending 1930; the increase in tractors is 191 per cent. The drawbar horse power increased slightly.

This study is based on a survey of 291 farms on which 314 tractors were used. The records were about equally divided between dairy farms in the southeastern part of the state; corn, beef cattle, and hog farms in the southwestern part; and small-grain farms in the northwestern part. The average size of farms in the three sections were 214, 294, and 556 acres, respectively.

No consistent relation exists between the size of farm and the size of tractor used.

Seventy-nine per cent of all of the tractors included in this study were purchased new.

On the farms studied, tractor power constituted slightly more than half of the drawbar power.

The number of acres handled per drawbar horse power was 14.7 in the southeast, 19.1 in the southwest, and 29.9 in the northwest.

The average hours of use per tractor per year was 417. The maximum was 2,615 hours and the minimum, 30 hours.

Approximately 75 per cent of all tractor work on the farms studied was drawbar work and 25 per cent belt work.

The most common drawbar operations were plowing, disking, spring-tooth harrowing, harvesting, and harrowing. The most important belt operations were threshing, feed grinding, silo filling, wood sawing, and corn shredding.

Sixteen per cent of all tractor work, 5 per cent of all drawbar work, and 47 per cent of all belt work was custom work.

The items of tractor cost considered in this study are fuel, oil, other lubricants, repairs, labor, interest, and depreciation.

The average cost per hour of operation was 74 cents and 96 cents, respectively, for two-plow and three-plow tractors. These costs varied from 40 cents to $1.96 per hour for the two-plow tractors and from 56 cents to $3.56 per hour for the three-plow tractors.

The most important factors causing variations in the cost per hour of tractor operation were the number of hours of annual use per tractor, the operations for which the tractors were used, the purchase price, the age, and the price of the fuel used.

Sixty-seven per cent of the tractor owners interviewed had increased the size of their farms since the purchase of the tractor. The average increase per farm was 80 acres. A 6 per cent increase in productive livestock per farm was reported.

An average net saving in man labor of 67 days per year after the purchase of a tractor was reported.

An average decrease of 0.18 hours in the daily hours of work per man, and an increase of 0.59 hours in the daily time spent in the field was estimated by the tractor operators as compared with the time so spent when the farms were operated with animal power.

The average reduction in work horses made possible by the use of the tractor was reported as 3.6 horses, or 33.6 per cent.

The tractor farmers reported an average reduction of 20 per cent in grain fed to work horses, 11 per cent in hay, and an increase of 29 per cent in pasture as compared with what was used before the tractor was purchased. They also reported the working life for horses to be 2.2 years longer.

The average decrease per farm in the cost of feed, labor, interest, and depreciation for work horses made possible by the use of the tractor, on the basis of market prices prevailing at the time of the study, was $489.17. On the basis of present prices (February, 1931), this reduction would be only $340.50.

The average cost of special tractor equipment per farm was $1,039.40, or $3.86 per crop acre.

Fifty-four per cent of all tractors included in this study were the three-plow size; 42 per cent were the two-plow size.

The number of tractors of the three-plow size and larger will probably soon far exceed the two-plow size.

Eighty-seven per cent of all owners interviewed operate the tractor themselves or have it operated by some member of the family.

Wet and soft ground was given by most operators as the chief obstacle to tractor operation.

Only 16 per cent of all tractors had extension rims.

The point of highest efficiency in tractor operation is slightly lower than the maximum capacity.

The cost per unit quantity of work performed with a tractor is less when the tractor is loaded to its highest efficiency point than when only a small part of the available tractor power is utilized.

Optimum tractor loads may be obtained by fitting the size of the implement to the capacity of the tractor or by hitching two or more kinds of implements behind the tractor at the same time.

The tractor may be operated continuously for relatively long periods of time.

Eighty-seven per cent of all owners interviewed stated that service for their tractor was available from a local dealer at an average distance of 6.2 miles.

Ninety per cent of those reporting on service stated that it was satisfactory.

Fifty-eight per cent of the owners interviewed did all of their own repair work; 82 per cent did more than half. Five per cent hired all their repair work.

One-third of the owners reported that their tractors were out of service when there was tractor work to be done. The average length of time was 2.9 days.

Ninety-five per cent of the owners stated that they intended to purchase another tractor when their machine needs to be replaced.

Some of the significant characteristics of tractor power are: (1) The tractor is a relatively large power unit. (2) Relatively large quantities of belt power are available. (3) Tractor power may be applied directly to drawn implements by means of the power take-off. (4) The tractor may be used continuously for long periods of time.

If the tractor is to prove a profitable investment, the farmer must so organize his business that the use of the tractor will either decrease the cost of farm operation without a corresponding decrease in income or else will increase the farm income more than it increases the operating expense.

APPENDIX

F.T.S. 1.1 Record No.______

FARM TRACTOR SURVEY

Division of Agricultural Engineering and Farm Management and Agricultural Economics
Department of Agriculture, University of Minnesota

SUB-PROJECT 1. SURVEY OF FARMS OPERATED BY EXPERIENCED TRACTOR OWNERS

County______Year ending______Date record taken______
Operator______Post Office______R.D.______
Town nearest farm______Distance and direction______
Soil type______Topography crop land______
Acres: Owned (this farm)______Cash rented______Shares______Rented out______
Total acres farmed______Acres in crops______Tillable land not cropped______
Rotation pasture______Acres perm. pasture tillable______Open past. not tillable______
Woods pastured______Woods not pastured______Farmstead, waste, roads, etc.______

CROP RECORD

	Before purchase		Year 192		Reason for changes
	Acres	Fields	Acres	Fields	
Corn for grain					
Corn for silage					
Other corn					
Oats					
Barley					
Rye					
Flax					
Potatoes					
Alfalfa					
Tame hay					
Wild hay					
Other crops					
Total					

F.T.S. 1.2 Record No.______

CONDITIONS BEFORE PURCHASING TRACTOR AND NOW

Livestock		Before purchase	Now	Reasons for changes
No. work animals kept				
No. needed now without tractor				
Grain fed work animals per year, lbs.				
Hay fed work animals per year, tons				
Pasture for work animals per year, days				
Care of work animals per day, hrs.				
Useful life of work animals, yrs.				
Average age work animals, yrs.				
Average weight work animals, lbs.				
Average value work animals, $				
Outside work by work animals for pay, days				
Cows, average number	Dairy			
	Beef			
Young dairy cattle & bulls				
Young beef cattle, bulls & steers				
Sheep				
Hogs				
Poultry				

Have you bought any work animals since getting tractor______

ANNUAL OPERATION COSTS

Repair parts	$	Expert labor	$	Railroad fares	$
				Express & cartage	
		Other costs		Trips for repairs	
				Telegraph & telephone	
				Cylinder oil:______gal.	
				Other oil & grease	
				Total	$

F.T.S. 1.3 Record No.________

DRIVER OF TRACTOR

Who drives tractor and age of driver: Farmer________Son________Hired driver________
Education ________
Mechanical training________

COST OF DRIVER

	Hired driver	Farm driver
Hired driver: mos.____days____hrs.____at____mo.____day____hr.____		
Farm driver: mos.____days____hrs.____at____mo.____day____hr.____		
Per cent of operation of tractor by hired and farm driver____		
Board furnished driver, ____mos. at $____; ____days at $____		
Value of house rent, farm products, etc., furnished driver____		
Driver insurance $________ License________ Etc.____		
Total cost of driver____		
Cost per tractor hour____		

FARM LABOR ON UPKEEP OF TRACTOR

Tractor Item	Man labor					Horse labor			Auto use on farm as tractor		
	Times or days	Hours per day or time	Total hours	Rate	Cost	Hrs.	Rate	Cost	Miles	Rate	Cost
Daily care											
Repairing											
Getting fuel, parts, etc.											
Total											

Items of repair________

How much of repairing is done by farm labor?________
Why? ________

F.T.S. 1.4 Record No.________

TRACTOR DRAW BAR WORK—HOME FARM

Kind of work	Total acres	Size tool	Hours Worked		Gasoline			Kerosene			Cash rec'd	Man hrs. saved
			Man	Tractor	Gals.	at	Total	Gals.	at	Total		
											X	
											X	
											X	
											X	
											X	
											X	
											X	
											X	
											X	
											X	
											X	
											X	
Total home farm draw bar work											X	

TRACTOR DRAW BAR WORK—CUSTOM

												X
												X
												X
												X
												X
												X
												X
												X
												X
												X
Total custom draw bar work												X

F.T.S. 1.5 Record No.________

BELT WORK ON FARM

Kind of work	Size of machine	Hours worked		Gasoline			Kerosene			Cash rec'd	Man hrs. saved
		Man	Tractor	Gals.	at	Total	Gals.	at	Total		
Total belt work home farm											

CUSTOM BELT WORK

Total custom belt work											
Total belt work											
Total draw bar work											
Total all work											

No. farms tractor worked on during year: Draw bar work________Belt work________
How many months of year is tractor under cover________
Value of building housing tractor $________Proportion used by tractor________%
Annual insurance on building $________

F.T.S. 1.6 Record No.________

TRACTOR RECORD

(If more than one tractor on farm use copy of this schedule for each)

Name of tractor________Rating________Year made________
Purchased: Date________From whom________Price________
New or secondhand and condition when bought________
Years used: Previous owner________By you________Years further service expected________
Value start of this year $________; End of this year________: Depreciation________
Avg. value________Interest on avg. value at________%________; Annual insurance________
Is tractor equipped with power take off?________
What operations is it used for?________

TRACTORS PREVOUSLY OWNED

Make	H. P.	Plows	Year new	Bought new or second-hand	Years used by former owner	Years used here	Cost	price	Reasons sold or discarded

MACHINERY ON FARM WHEN TRACTOR WAS BOUGHT THAT HAS BEEN SOLD OR JUNKED BECAUSE OF TRACTOR

Kind	Size	Bought		Years used	Sold, idle or junked	Date	Price rec'd or value now	Rented	
		Date	Cost					Days	Cost

F.T.S. 1.7 Record No.__________

MACHINERY USED WITH TRACTOR

Including all old machinery and any new machinery bought to use with tractor

Kind	Size	Bought		Value now	Kind	Size	Bought		Value now
		Date	Cost				Date	Cost	
What machinery could you dispose of because of tractor?									

OTHER MOTORS ON FARM BESIDES TRACTOR

Kind and make	Size	Date bought	Cost	Value now	For what used
Auto					
Truck					
Gasoline engines					
Electric motors					

F.T.S. 1.8 Record No.__________

TRACTOR EXPERIENCE

1. On plows do you use break-pin hitch?__________Spring-trip hitch?__________
   If spring hitch, what type__________
2. Do you ever pull more than one implement of the same kind or different kinds?__________
3. If so, what hitch is used?__________
4. Do you use automatic steering device?__________What kind__________
5. On continuous job how many hours daily is tractor operated__________Horses__________
6. Is any tractor operated equipment owned co-operatively?__________
7. What are the principal difficulties you have in operating your tractor__________
8. Did you purchase your tractor of a local dealer?__________
9. What were terms of purchase?__________
10. What discount was given for cash payment in full?__________
11. Where do you get parts and service?__________Miles distant__________
12. Hours to get parts__________Is service satisfactory?__________
13. How many days lost this year because tractor was out of service?__________
    Why? __________

14. Has operator ever been injured by tractor? ________________

15. Do you consider a tractor more dangerous than horses? ________________

16. Because of the use of tractor on this farm has additional land been purchased? ________ acres. Additional land rented ________ acres?

17. Have you ceased cultivation of any land because of the use of tractor? ________ acres

Reasons ________________

____

F.T.S. 1.9 Record No. ________

18. Land brought into cultivation { drained / cleared / broken } because of tractor ________ A.

19. Changes in farm layout made or contemplated because of tractor ________________

____

20. Does tractor have wheel extension rims? ______ Do you use them? ______ Why? ________

____

21. Tractor work hired before getting tractor: Days ______ Cost $ ______ Kind of work

____

22. Days tractor does horse work while horses are idle ______ Why? ________

____

23. For what operations is tractor preferred to horses? ________________

________________ Why? ________________

24. How many hours has tractor lengthened ______ or shortened ______ work days on farm?

25. How many hours has tractor lengthened ______ or shortened ______ work day in field?

26. How much more or less labor used on farm now than before tractor was bought.

Family labor: Man months ______ Man days ______, more or less

Hired labor: Man months ______ Man days ______, more or less

27. For what operations are horses preferred to tractor? ________________

________________ Why? ________________

28. For what operations have you found tractor unsatisfactory ________________

________________ Why? ________________

29. Do you work shifts of drivers on tractor? ______ Method ________________

30. Do you work tractor nights by artificial lights? ______ Total hours ________________

31. Chief advantages of tractor on your farm ________________

____

32. Chief disadvantages of tractor ________________

33. If you had no tractor would you buy one? ______ Kind ______ Why ________

________________ What H. P. ______ Why? ________________

34. Has your tractor been a profitable investment? ______ Why ________________

____

35. Farmer as co-operator in tractor accounting ________________

Enumerator ________________