ABSTRACT

MASTER'S THESIS

ECONOMIC ANALYSIS OF FARM MACHINE COSTS

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Submitted by

Atar Singh

In partial fulfillment of the requirements

for the Degree of Master of Science

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ABSTRACT

The importance of mechanization in agriculture has been recognized in almost every country of the world. In the beginning of agricultural mechanization in the United States, the main emphasis of the scientists, engineers, research workers, machinery manufacturers and the farmers, was on the comparative costs of animal and machinery power per acre.

Now, with almost complete mechanization of farming, the investigators are focussing their investigations on the machinery working costs for developing ways and means to improve the working efficiency for most economical results.

The author is a graduate student from India, where mechanized agriculture is still in its infancy, but earnest efforts are being made by the India government for its development. It is with this problem in view that the author took up these studies for his thesis. The present studies are confined to the economic phases of farm machines only.

<u>Problem</u>. What are the requirements for efficient use of mechanical equipment in crop production?

Problem analysis. In order to answer the problem, the following questions are to be analyzed.

1. What items constitute the cost of equipment?

2. What are the limiting factors which govern such costs?

3. How can the cost under each be lowered?

4. What are the limiting factors in the time requirements for different operations?

5. What differences in cost per acre are secured by different methods?

6. How far can these differences be overcome through efficient management?

Delimitations. Analysis was confined to data secured in 1947-48 from farmers on irrigated farms in the Weld county, Colorado and compared with,

a. Analysis of data secured from the representatives of farm machinery companies.

b. Analysis of published data in certain experiment and technical reports.

c. Interpretation of observations.

To analyze this problem, data were collected from the following sources:

1. Actual cultivating data secured in 1947-48 from farmers on irrigated farms in Weld county, Colorado.

2. Actual records of tractor details, in regard to cost, repairs, number of working days, area of the farms on which maintained and working hours per year from farm records as in number 1.

3. Data about the tractors as given by the machinery companies.

4. Published data having direct bearing on the present problem.

5. Personal observations and records obtained in the field about working conditions, especially actual tractor speed.

a. Actual cultivation data on barley, potatoes and bean crops were collected by the survey method by the economics section staff in 1947-48. The form used is given in the Appendix. These data were analyzed by the present writer by the use of the Burdick equation to find out the crew hours per acre and to compare these calculated hours with the time as per farmers estimate. The equation used is explained in the following pages. The time for turns, rest and service and length of the field used in the equation were the same as pointed out by the farmers. In cases where such time was not mentioned on the survey sheets, the time was taken as

0.5 minutes for turns and 33 per cent of the actual working time for rest and service. The speed of the tractor was used as specified by the tractor firms. The width of the implement was as reported by the farmers. Because records for effective width were not secured, only an estimated average width of operation can be assumed. After calculating and comparing the crew hours with farmer's estimate, it was noticed that in some cases the difference between the two figures was abnormal, indicating errors in securing the original data. Such records were therefore discarded while working out the averages.

b. The same survey data for the entire farms were used for sorting out the tractors in regard to the cost, depreciation, repairs, estimated life and average use per year as per records of these farms. To make the figures more representative, tractor records were also taken from the data similarly collected for sugar beet production. All of these records were used to analyze fuel consumption for the tractors. The tractors were grouped on the basis of make and model and rated Drawbar H.P.. The fuel consumption was analyzed on an hourly basis and averages for each group of tractors were calculated. This average was used in calculating the working costs of tractors.

c. Data for tractors as given by the manufacturers were taken from the "Red Tractor Book", 1948, Implement and Tractor, Kansas City, Missouri. Records for the tractors kept at these farms were taken from this book, such as the rated Drawbar H.P., fuel consumption on rated loads and fuel consumption at varying loads as compared with fuel consumption in the actual field working.

d. Published data giving certain details, which gave clues to points connected with the present problems here studied in the review of literature.

e. During the fall quarter a number of field operations were observed and records were secured on the working of the tractor and different equipment. Careful observations were taken about the working speed of the tractors. The actual time to cover field distances was recorded. Average time required by different tractors to travel measured lengths of the field was taken and the average speed in miles per hour was calculated and compared with the specified speeds.

The present study emphasizes two aspects of machine costs, as enumerated under problem analysis. The first item under these costs is the working costs of equipment, especially the tractors.

Among the biggest items in the cost of farm operations are equipment and power. Each incorporates both constant and variable costs. The constant costs are those which have to be accounted for regularly, irrespective of the amount of use of the machinery, such as depreciation, interest and annual repair costs. The variable costs constitute the actual running costs from day to day.

The significant results under these costs are detailed below:

1. The costs under depreciation and interest could be reduced to a minimum point by adjusting a well-balanced land and equipment combination. By analyzing these costs on per acre basis was found that where-as the cost on a per acre basis was $1.68 on a 160 acre farm, it increased to $3.73 on a 40 acre farm and was $2.35 on an 80 acre farm, i.e. every reduction in area to half increased the per acre costs by about 50 per cent.

2. The area of the farms under study varied from

40 to 160 acres per tractor. The average cultivated area for farms was 76 acres.

3. The average life of tractors at the farms under study was estimated to be 14 years with an annual use of 731 hours compared to about 500 hours reported in other studies.

4. The following items of cost in terms of percentage of new cost were,

	per cent
a. Depreciation	6.73
b. Interest	3.50
c. Repairs	7.17

5. The tractors maintained at the farms under study varied in their drawbar horse power. The average drawbar horse power per tractor was 17.4.

6. The average annual repairs cost of tractors in terms of dollars was almost equal to the average crop area of the farms under study. The cost under this item was, therefore, calculated at $1.00 per acre of crops.

The variable or day to day costs included the cost of fuel, oil and operator's wages, and the results are detailed below.

1. The average fuel consumption of tractors with an average of 17.4 D.B.H.P. was 1.47 gallons per hour.

2. The per hour consumption of tractors in the study was on the average of about 78 per cent of the fuel consumption at rated loads, as noted in Nebraska tractor tests.

3. Working costs at 25 cents per gallon for fuel, 80 cents per gallon for oil and 75 cents per hour for the operator's wages came to $1.14 per hour for these items.

The second item to be emphasized is the factors in time requirements for different operations. In the actual working of the machinery on the farms, the time requirements is affected by a number of factors or variables. They may influence individually or in combination. To study the influence or significance of any one variable, it is necessary to keep other variables as constant as possible. In this study too, the results which indicated normal field operations were taken. In this study the following factors appeared outstanding in governing the time requirements of particular operations.

1. Speed of the tractor.

2. Width of the machine.

3. The time required for servicing, rest and minor repairs to outfit during operations.

4. The time required for taking turns at the ends of the field.

For calculating the actual crew hours per acre the following equation as formulated by Burdick(5), 1947, was used.

$$T = \frac{8.25}{SW} \left(1 + \frac{16SN}{3L} \right) (1 + A)$$

T is the time or crew hours per acre.

S is the speed of tractor travel in miles per hour.

W is the width of implement or machine used.

L is the length of the field in rods.

N is the time required for turns at the end of the field, expressed in fraction of a minute.

A is the time required for overall service and rest allowance, expressed as a decimal figure, e.g. if a farmer estimates that he used 10 minutes for every hour for A, then A as expressed in decimals will be $\frac{10}{50} = .2$.

1. The speed of the tractor: it was affected by one or more of the following factors.

   a. Wheel slippage on light textured soil and steep slopes.

   b. Lowering of the speed in heavy or hard soil, due to heavy draft and jerks.

   c. Wheel slippage and lower speed in stony and rough surface soil or soil covered with more organic matter or humus.

d. Use of clutch too often.

In field observations it was found that in practice the field speed varied from 7 to 18 per cent below the maker's specified speed. But the results of the data analysis indicated that the speed was from 5-10 per cent below that specified by the tractor companies.

2. Width of the machine. In the use of such machines as eversman, float harrow and spring tooth, a certain amount of overlapping has to be done. And the effective width of such machines in field work is always less than the actual width. In actual field observations, it was marked that an overlapping of about a foot to a foot and a half is usually done. The total width of these machines as distinct from the width effective in operation varied from 11.16 feet in case of eversman to 18.8 feet in case of spring tooth under the present study. This reduction in the effective width was considered to affect the total time requirement from 5-10 per cent.

3. The time required for servicing, rest and minor repairs to outfit during operations. To study the influence of this factor, the data were analyzed after allowing 0.1, 0.2 and 0.35 or 10, 20 and 35 per cent of the working time under this factor. Taking other factors into consideration and applying

them to the results, it was found that an allowance of 0.2 or 20 per cent of the actual working time reflected the usual conditions.

4. The time required for taking turns at the ends of the field. The average time used for this factor in data analysis was based on actual records. It varied from 0.2 to 1 minute per turn. It therefore may be assumed that for general operations the average time is about 0.5 minutes per turn.

Apart from these, other factors affecting the time requirements were:

1. Size, shape and the length of the fields.

2. Width of the machine with reference to the total number of turns necessary per acre.

3. Maintenance and up-keep of the machine.

4. Handling and care of machines during operations.

5. Efficiency of the operator.

The present study and analysis of data presented a number of side issues, which require further investigation for precise results. Suggestions for further study:

1. To find out the best combination of land and equipments to reduce the working costs to the most economical and efficient point.

2. To study the relation of repair costs to the total working life of equipment.

3. Further investigation and analysis of field survey data for more precise results on slippage of tractor wheels and overlapping of implements.

4. Investigations for suggestions to farmers for optimum use of tractor power and its working life.

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Chapter I

INTRODUCTION

The importance of mechanization in Agriculture has now been recognized by almost every country of the world. A review of the history of Agricultural mechanization of this country shows clearly that the main emphasis of the scientists, the engineers, the research workers, the manufacturers and the farmers has been on the comparative costs of the animal and machinery power per acre.

In the beginning only high power tractors were manufactured, and where-as these heavy and costly pieces of equipment proved their economic advantages on bigger farm units, they could not be utilized by smaller unit farmers. During the last decade or so, the manufacture of different low power and general purpose tractors with different sizes of equipment, suitable and economical even for smaller farms, coupled by a greater demand for farm products, increase in prices and shortage of labor during the last war, brought about a quick change in the mechanical development of different countries.

Now with almost complete mechanization of farming, the focus of investigations in farm working costs has changed from comparative studies of animal and machine power to studies in working cost of machines and developing ways and means to improve the working efficiency for most economical results, many studies have been made in this direction. The trend of mechanization in the United States is shown by the United States census of Agriculture 1945, Volume II (27), 1947.

Table 1.--TRACTORS ON FARMS:--(UNITED STATES).

Item and Year	Farms reporting Number	% of all farms	Total number of tractors
Tractors on farms			
1945	2,002,662	34.2	2,421,767
1940	1,609,697	23.1	1,567,430
1930	851,457	13.5	920,021
1925	473,848	7.4	505,933
1920	229,332	3.6	246,083

The author is a graduate student from India where mechanized Agriculture is still in its infancy. The shortage of farm products due to shortage of labor, dependence upon imported chemical fertilizers and the high cost of other manure during the last war years, resulted in decreased yields per acre. The decreasing yields of farm products and comparatively increasing population, have made it all the more necessary to introduce mechanization in agriculture; to plow new tillable areas to increase the acreage under food crops and finally to help agriculture to increase crop yields per acre. It is with this development in view that the author has come to this country to study different aspects of agriculture. The present studies are confined to the economic aspects of farm machinery.

The problem

What are the requirements for efficient use of mechanical equipment in crop production?

Problem analysis.--

1. What items constitute the working costs of equipment?

2. What are the limiting factors which govern such costs?

3. How can the cost per acre under each be lowered?

4. What are the limiting factors in the time requirements for different operations?

5. What differences in "cost per acre" are secured by different methods?

6. How far can unfavorable cost factors be overcome through efficient management?

Delimitations.--Analysis herein is confined to data secured in 1947-48 from farmers on irrigated farms in Weld county, Colorado, as compared with,

(a) analysis of data secured from the representatives of farm machinery companies,

(b) analysis of published data in certain experiment stations and technical reports,

(c) personal observations.

Chapter II

REVIEW OF LITERATURE

The literature referred to in this chapter has been reviewed with particular emphasis on the requirements for efficient use of mechanical equipment in crop production. The problem has two aspects, i.e. (a) factors governing costs and (b) factors in the labor requirements for different operations. Many studies have been made covering the above factors.

Burdick, and Pingrey, (6), in their study "Cost of producing crops on irrigated farms", (1929) analyzed detailed cost data for the years 1922 to 1927 and calculated the working cost of tractors per hour and average cost of production of different crops at these farms with the idea of:

1. Aiding the individual farm operator in becoming more familiar with his own business enterprize.

2. Reporting hours of man and power, which could be used in planning the farm program.

3. Pointing out that future farming needs an alert, keen and business like supervision, a willingness to learn by experience, a willingness to exchange views and to seek for better methods.

The calculated cost for tractors was $1.00 per hour.

Starch (25), in his studies "Farm organization as affected by mechanization", (May 1933), attempted to explain the causes of variation in each of the cost elements entering into a job, and attributed these to a number of factors covering the constant and the variable costs. The studies were mainly directed:

1. To study the functioning of economic principles with the farm organization.

2. To determine the best labor, land and equipment combinations and size of the unit required.

3. To test the adaptability of types of equipment to great plains farms.

4. To analyze the factors of production with the view of determining the lowest cost method of organization. Some of Starch's findings were as follows:

(a) Percentage of actual field work to the total time in case of plowing varied from 75-92%.

(b) The working cost per acre with 4-plow equipment varied from $1.44 to $2.29 under different working conditions of the field.

(c) The differences in percentage between total reported time and the actual working time were;

(1) plowing (in stony ground) 18-22%

(2) seeding and combining 26-38%

(3) disking, duck-footing and harrowing 11-22%

(d) A 3-plow tractor working about 10 hours per day in the field with the machines listed will have a daily capacity;

	Per Day
(1) plowing 3-bottom plow	10 acres
(2) disking 10ft. width	30 acres
(3) cultivating 12ft. width	40 acres
(4) seeding 14ft. width	50 acres
(5) combining 10ft. width	28 acres

(e) The best combinations for a wheat farm, one half cropped and one half fallow, as related to size of tractor;

(1) 3-plow tractor	200 acres
(2) 4-plow tractor	1100 acres
(3) 6-plow tractor	1800 acres
(4) 10-plow tractor	3000 acres

(f) The typical total cost per acre for a number of common jobs, with labor at 35¢ per hour and fuel at 22¢ a gallon and oil at 20¢ a quart was:

one way disking	$ .53
tandem disking	.52
duck-footing	.43

spike tooth harrowing	$ .16
disking and drilling combined	.80
plowing	1.72
spring tooth harrow	.30
seeding	.37
cultivating corn	.31

(g) Reduction in costs could be secured by:

(1) eliminating inefficiency in operation,

(2) removing maladjustments in farm set-up,

(3) developing new techniques,

(4) introducing cost saving equipment.

Schwantes (23), in his work "Keep the tractor pulling its optimum load", (May 1939), gave an account of the data obtained from operators of 300 tractors in various parts of Minnesota. He calculated average costs for all farm operations and pointed out the differences in costs, when the tractor is not utilized for pulling its optimum load. The main points of his study were:

1. The relationship between the size and type of tractor to;

(a) size of farm

(b) soil

(c) type of farming

2. Optimum load of a tractor is usually considered to be about 80% of its maximum load.

3. The cost per acre was doubled when only 38%

of the power of the tractor was utilized.

Hertel and Williamson (12), under "Cost of Farm Power and Equipment", (April 1941), gave out their findings based on a survey of 438 New York State farms for 1936 and complete cost records kept by 75 farmers for 1938-39. They formulated an equation for calculating the crew hours required to work an acre and number of acres worked in 10 hour day with given width of machine and the tractor speed in miles per hour as illustrated.

1. Acres per 10 hour day = (width in inches x miles per hour) ÷ 10.

2. Hours per acre = 100 ÷ (width in inches x miles per hour).

The main points of their study were:

(a) Time per acre and cost per acre of different field operations.

Implement	Time per acre hours	Cost per acre dollars
plowing	2.0	$2.09
spring tooth harrow	.5	.45
disc harrow	.7	.67
grain drill	.6	.82

(b) Factors affecting operative costs of equipment were; age, use, size of tool, housing and care.

(c) Methods of lowering the operative costs were; use of second-hand equipment, cooperative use of equipment, share ownership, hiring, exchanging and borrowing equipment.

In a study made by engineers in the Nebraska tractor tests (18), 1920-1941, it was pointed out that drawbar horse power rating is about 75 per cent of the maximum corrected horse power and also that the fuel consumption of tractors at varying loads was about 75 per cent of the fuel consumption at rated loads. Results in terms of percentage of slips of drive wheels were also observed. In the case of tractors with rubber tires and for different makes, the slippage varied typically from 4.45 per cent to 9.6 per cent.

Davidson and Henderson (11), under "Life Service and Cost of Service of Machines on 400 Iowa Farms", (January 1942), studied the effects of size of equipment and crops on equipment use on these farms. They pointed out the role of machines in the Agricultural practices in Iowa and pointed out factors which govern the working costs:

1. There were no definite relationships between the hours of use per year and the life of equipment.

2. Interest, cost of housing, insurance and taxes were 5.0, 1.4, 0.2 and 0.4 per cent respectively on the average investment.

They also pointed out ways for reducing farm machine service costs per acre.

1. To extend the life of the machine.

2. To extend the use of machine in the number of days service per year.

3. Cooperative ownership of machines.

4. Custom work.

Richey (22), in his studies "Cost per hour of using farm machines", (March 1942), pointed out that the biggest item in the cost of producing crops is that of equipment and power. The idea of these studies was:

1. To help the farmer to be able to analyse costs and to predict future costs.

2. To form a basis for selecting new equipment in order to keep the costs as low as possible for any particular situation.

Richey gave a detailed method of determining costs of operations and brought out the following figures:

1. Interest, housing, taxes and insurance were 4.0, 1.0, 1.6 and 0.4 per cent of average investment cost respectively.

2. Machine costs.

Machine	Years until obsolete	Hours to wear out	Total repair cost in % of new cost
Tractor plow	15	2000	20
Disc harrow	15	2000	30
Grain drill	20	1200	20
Tractor	15	7500	35

Morrison and Baumann (16), under the article "Labor, power and machinery", (June 1942), confined their studies to Medina and Miami county farms in Ohio, to find out the relation between the size and type of a tractor to annual and hourly costs. The results of their studies for a general purpose two-plow tractors were:

1. Number of tractors studied	63
2. Average age of tractors in years	4.2
3. Average value	$500.00
4. Hours of use per year	226
5. Fuel per 10 hours (gallons)	13.0
6. Oil per 10 hours (quarts)	1.5

Advantages of having a tractor as pointed out by the investigators were:

1. Work can be done more seasonably.
2. Work is made easier for the operator.
3. More livestock can be kept.
4. Less labor is required to operate a farm.
5. Number of work hours per day is reduced.

Mumford, Kennedy, Virgil and Davis (17), in their studies "Cost of operating power equipment on Oregon farms", (June 1942), calculated the operating costs of 350 tractors in the Williamette Valley and Columbia basin, to determine:

1. The cost of operating tractors.
2. The relative importance of different cost

items, making up the total cost of operation.

3. The effect of size, age and season's use of other tractors on the operating costs.

The results of the data collected were as follows:

Number of tractors in the study	49
Rated drawbar H.P.	14-17
Average age of tractors	5.4
Average value	$679.00
Depreciation in 1940	$101.00
Gallons oil per 100 hours	4.5
Seasons use (hours)	749
Gallons fuel per hour	1.94

The committee on farm machinery Rental schedule of American society of Agricultural Engineers, in "Rental rates for farm Machinery" (21), (January 1943), discussed a technique for calculating rates at which farm machines could be rented out by the owners. To arrive at rental rates reasonable for both parties, they set a schedule of important variables which affect the cost of service.

1. It was thought that the machines which are rented out would probably be used around 50 per cent more than previously, then the average cost was calculated on the basis of about 150 per cent more hours of use as compared to the corn belt average hours.

2. Depreciation was calculated on straight line basis i.e. estimated hours of life with the listed purchase cost.

3. Repairs were estimated as a total for the life of the machine, expressed as a percentage of the new cost.

4. The combined annual charge for interest, housing, taxes and insurance was calculated at 7 per cent of the average cost.

The main points concerning the above study were:

Machine	Basic hours of life with repairs shown	Total repair cost in % of new cost	Hours of use per year
Tractor plow	2000	20	200
Disc harrow	2000	30	150
Spring tooth harrow	2000	30	120
Grain drill	1200	20	80
Cultivator	2500	30	150
Tractor	7500	35	500

Kalbfleisch (13), in his study "Cost of operating farm machinery", in eastern Canada, (1943), discussed the methods of calculating the machine costs on per acre as well as per hour basis. The results arrived at were:

I. Machine	Size	Approximate new cost	Estimated life (years)	Estimated acres for life	Repairs as % of new cost	Labor as % of repair cost
Plow 3-furrow	10in. to 12in.	$180.	15	1500	90	25
Disc harrow	10ft.	$160.	15	4000	30	50
Grain drill	7-8ft.	$170.	25	1500	30	50
Grain binder	10ft.	$400.	15	2000	60	50
Combine	5-6ft.	$800.	15	1500	40	50

II. Tractor class	Drawbar H.P.	Fuel consumption per day gallons light	medium	heavy
one plow	6-10	5	8	10
two plow	10-14	8	10	12
2-3 plow	14-20	10	14	18
3-4 plow	20-26	14	18	22

According to his study cost varied according to the condition of the soil, size of the field, stones, maintenance of machines, care in operation, cost of fuel. He also gave a basis for certain rules for renting out the machines.

Burdick (4), April 1943, developed a handy guide for calculating rental charges on farm machinery per crop acre. There-in he developed the method of calculating such costs, based upon work done by others. The chart pointed out costs of implements and machines other than tractors, tractors were omitted because no allowance was calculated for fuel and oil for tractors. As an illustration; taking the investment in a machine as \$100.00, the annual average cost charged was \$15.00 or 15 per cent on the first cost. The working costs for this machine on a 20, 40 and 80 acre basis were \$0.75, \$0.375 and \$0.188 per acre respectively.

Stippler (26), under his studies "A method of approach to farm power studies", (July 1944), analysed the data of 277 tractor farms in Idaho. He pointed out a method for determining power requirements for field operations on farms that are to be used as standard for a particular area. Regarding the fuel consumption under actual field conditions, he took illustrations from the Nebraska tractor test data, wherein the fuel consumption under rated load and under varying loads were noted for a particular tractor. In these tests the fuel consumption under varying loads was about 75 per cent of the fuel consumption under rated loads. According to the author, the fuel consumption under farm conditions may be higher as the tractors on farms may not be so completely in adjustment as were the tractors used in Nebraska tests. An adjustment in rated loads was said to be desirable before using the Nebraska tests data for farm conditions. His studies indicated that actual acreage for plowing reported by farmers was 84 per cent and that for harrowing 76 per cent of the acreage calculated by the formula.

Major advantages of the method discussed:

1. Distinction between power requirements and power consumption.

2. Determination of energy requirements per unit of implement under farmers operating conditions, also to check the reasons of inefficiency in operation of power employed on farms.

3. The analysis of energy used for individual field operation will provide the basic information needed to determine the proper relationship between size and type of farm organization and size and type of power units and implements.

Increasing mechanization of agricultural production emphasized the need for studies of the use of farm power and suggested the necessity of more accurate measures for power requirements and power consumption in agriculture.

Following are the extracts from survey data:

Field operation	Machine width	Tractor speed	Total hours per day	Actual hours of work per day	Man hours per acre
Plowing	14 in.	4.33	10.5	10	1.8
Disking	6 ft.	3.34	10.5	10	.6
Seeding grain	6 ft.	4.33	4.0	3	.6
Cultivating	6 ft.	3.34	2.0	7.5	.7

Barlow (1), May 1947, studies the cost of operating tractors, machinery and equipment on farms in the Delta Cotton areas. He based his data on the detailed records for 179 tractors found on 120 farms. His study revealed that the factors affecting the cost of operation were size, wheel type and amount of annual use. The average cost of operating all tractors with rubber wheels was \$5.48 per 10 hour day. It ranged from \$4.98 per 10 hour day for small tractors on rubber to \$5.85 for large tractors on rubber. The average annual use was 103.6 days for rubber and 78.5 days for steel wheels.

Burdick (5), June 1947, in his bulletin "A new technique of field crop labor analysis", developed an equation for calculating crew hours per acre with given field data. The equation is as under:

$$T = \frac{8.25}{SW}\left(1 + \frac{16SN}{3L}\right)(1 + A)$$

T is the time required per acre.

S is the speed of the tractor in miles per hour.

W is the width of the machine in feet.

N is the time in minutes per turn.

L is the length of the field in rods.

A is the over-all time required for service, rests, etc., expressed in percentage of the actual running time.

This study was made to furnish material for answering farm management questions about the valley i.e. (Fort Collins, Eaton, Greeley area) from which the data were secured. The author indicated that the following factors should receive more analysis to find the effects upon the number of hours per acre required for various operations.

1. Length of field.
2. Width of machine.
3. Speed of travel.
4. Time required for turns.
5. Soil and weather conditions.
   a. Making extra operations necessary.
   b. Slowing up speed of travel.
6. Possibility of combining operations or of overlapping.
7. Service time required for necessary servicing of machinery and for rest and unknowns.
8. Distance from farmstead to fields.
9. Uncertainties, such as,
   a. Shape of field.
   b. Effect of sustained long hours upon efficiency.
   c. Slippage of tractor wheels.
10. Unexpected breakage of delays.

The author also indicated that the average time for N was about ½ minute and that A should be about 20 per cent and may vary up to 35 per cent for making allowance for slippage of tractor wheels. The equation gives an agricultural economist a powerful tool of analysis, which can be applied to the conditions on the individual farm with a high degree of confidence in results. The equation proved effective in analyzing the individual operation data, and would enable one to distinguish between labor requirements under a given set of conditions, in comparison with the highest degree of efficiency under any set of conditions.

Shaw (24), in his Thesis "Labor Requirements-Irrigated Farms", 1947-48, analyzed the survey data secured by the economic section of Colorado Agriculture Experiment Station and calculated labor requirements for the cultivation of certain crops. During this study he analyzed the farmers estimate for specific operations by means of the Burdick equation as compared to the farmer's estimated crew hours. The results were as shown below:

I. Operation	Machine width ft.	Field length rods	Tractor speed miles p.h.	Hours of survey per acre	Hours by equation per acre
plowing	2.3	60	3.52	1.4	1.56
diskingb	8.0	75	3.67	.52	.42
harrowing	15.0	60	3.75	.42	.27
floating	12.0	60	3.75	.29	.24

Summary:--In the foregoing review of literature, only that portion of the literature was quoted, which had reference to the present study. The present study involves two aspects of costs:

I. The tractor working costs and their relation to per acre operation costs.

II. Actual operation costs and their relation to factors which affect such costs. These are summarized below.

From the foregoing review of literature of studies by Starch (25), 1933, the main points in regard to cost and work were:

1. The working costs for tractors varied from \$1.44 to \$2.29 per acre.

2. Comparison between running time and total time;

a. Running time as percentage of total time 75-92.

b. Rest and service time as percentage of total time for;

(1) plowing in stony ground	18-22
(2) seeding and combining	26-38
(3) discing and harrowing	11-22

Schwantes (23), 1936, in his studies found that the optimum load for a tractor is about 80 per cent of its maximum load and that the working cost of tractor per acre doubled when only 38 per cent of its power was used.

Burr (8), 1941, calculated the following figures from his studies for the cost and time required for different field operations.

Name of operation	Cost per acre	Average time required hours per acre
Plowing	$2.09	2.0
Spring tooth	.45	.5
Disc harrow	.67	.7
Grain drill	.82	.6

Under the Nebraska tractor tests (18), the following results were arrived at:

1. The drawbar horse power rating was 75 per cent of the maximum corrected horse power.
2. Fuel consumption at varying loads was about 75 per cent of the consumption at rated loads.
3. The slip of drive wheels was from 4.45 to 9.61 per cent.

Richey (22), 1942, from his studies calculated the following figures:

Name of implement or machine	Years until obsolete	Hours to wear out	Total life-time repair cost in % of new cost
Tractor plow	15	2000	20
Disc harrow	15	2000	30
Grain drill	20	1200	20
Tractor	15	7500	35

Mumford (17), 1942, in his studies on tractors data made out that the tractors with an average ratio-drawbar horse power from 14 to 17 required 4.5 gallons of oil per 100 hours and 1.49 gallons of fuel per hour. The average hours of use per season were 749.

Results of tractor data under Rental rates (21), 1943, showed the following details for tractors.

1. Average total life in hours 7500
2. Life-time repair cost in per cent of new cost 35
3. Hours of use per year 500

Kalbfleisch (13), 1943, under his studies on fuel consumption in relation to drawbar horse power, found out the following figures:

Tractor class	Draw-bar H.P.	Fuel consumption per day (gallons) light	medium	heavy
2-plow	10-14	2	10	12
2-3-plow	14-20	10	14	18
3-4-plow	20-26	16	18	22

The working cost for a hay mower (cost $110.) on acre basis was $o.29 on a 40 acre farm and $0.18 on an 80 acre farm. Similarly the working cost of tractor (operators wages not included) was $6.95 per day when worked 500 hours per year.

According to studies made by Burdick (4), 1943, the average working cost of machines costing $100.00 was $0.75, $0.375 and $0.188 per acre on 20, 40 and 80 acre farms respectively.

In another study by Burdick (5), 1947, on farm machine field operation data he showed that the time required was about 0.5 minutes per turn and that from 20-35 per cent should be added to running time, including wheel slippage.

Stippler (26), 1944, from his studies found the following results. Area per unit of time reported by farmers as a per cent of calculated acreage was; plowing 84 per cent and harrowing 76 per cent.

Extracts from his studies are given for man hours per acre for specific operation.

Name of operation	machine width	tractor speed	man hour per acre
plowing	14"	4.33	1.8
disking	6'	3.34	.6
seeding grain	6'	4.33	.6
cultivating	6'	3.34	.7

Barlow (1), 1947, in his studies found that the average operating tractor costs were as under:

Tractor class	kind of wheels	annual use-days	cost per day
small	rubber	103.6	$4.98
large	rubber	103.6	$5.85

Chapter III

METHODS AND MATERIALS

As detailed in the introduction chapter, the problem of the study was to find out the factors necessary for the efficient use of mechanical equipment in crop production. To analyze this problem, data were collected from the following sources:

1. Actual cultivating data secured in 1947-48 from farmers on irrigated farms in Weld county, Colorado.

2. Actual records of tractor details, in regard to cost, repairs, number of working days, area of the farms on which maintained and working hours per year from farm records as in number one.

3. Data about the tractors as given by the machinery companies.

4. Published data having direct bearing on the present problem.

5. Personal observation and records obtained in the field about the working conditions, especially actual tractor speed.

a. Actual cultivation data on barley, potatoes and bean crops were collected by the survey method by the economics section staff in 1947-48. The form used is given in Appendix. This data was analyzed by the present writer on the basis of the Burdick equation to find out the crew hours per acre and to compare it with the time as per farmer's estimate. The equation used has been explained in the review of literature and analysis of data. The time for turns, rest and service used in the equation was the same as pointed out by the farmer as well as the length of the field. In cases where such time was not mentioned on the survey sheets, the time for turns was taken as 0.5 minutes and for rest and service, 33 per cent of the actual working time. The speed of the tractor was used as specified by the tractor firms, the width of the implement was the actual width reported by the farmers. Because records for effective width were not secured only an estimated average width can be assumed. After calculating and comparing the crew hours with farmer's estimate, it was noticed that in some cases the differences between the two figures was abnormal, indicating errors in securing the original data. Such records were therefore discarded while working out the averages.

b. The same survey data for the entire farm were used for sorting out the tractors in regard to the cost, depreciation, repairs, estimated life and average use per year as per records of these farms. To make the figures more representative, tractor records were also taken from the data similarly collected for sugar-beet production. All of these records were used to analyze fuel consumption for the tractors. The tractors were grouped on the basis of make, model and Rated Drawbar H.P.. The fuel consumption was analyzed on an hourly basis and averages for each group of tractors were calculated. This average was used in calculating the working costs of tractors.

c. Data for tractors as given by the manufacturers were taken from the "Red Tractor Book" 1948, Implement and Tractor, Kansas City, Missouri. Records for the tractors kept at these farms were taken from this book, such as the Rated Drawbar H.P., fuel consumption on rated loads and fuel consumption at varying loads as compared with fuel consumtion in the actual field working.

d. Published data giving certain details, which give clues to points connected with the present problems have been mentioned in the review of literature.

e. During the fall quarter a number of field operations were given personal observation and records were secured on the working of the tractor and different equipment. Careful observations were taken about the working speed of the tractors. The actual time to cover field distance was recorded. Average time required by different tractors to travel the measured lengths of the fields was taken and the average speed in miles per hour was calculated and compared with the specified speeds.

Chapter IV

ANALYSIS OF DATA

The present study covered two aspects of machine costs and time requirements for different operation, as enumerated under Problem Analysis.

I. Factors governing working cost of equipment especially tractors, one of the biggest items in the cost of farm operations is the equipment and power. The following items constitute the working costs of equipment.

A. Depreciation due to wear: this is mostly calculated in two ways;

1. The original investment is spread over the average estimated life of the equipment.

2. Relationship between length of life and total repair costs; operating conditions apparently are more important than machine quality, mechanical deterioration or life time wear in affecting repair costs. The important items are:

a. Amount of use

b. Specific operation conditions

c. Care by operator as in lubrication, adjustment, repair and shelter.

B. Obsolescence

1. Tractor mounted tools made specially for one make of tractor become obsolete when their tractor becomes obsolete, regardless of their own condition.

2. New inventions and changed farming practices may make a machine obsolete. Some of these items are:

a. Increased efficiency of new machine doing the same job.

b. Development of new methods eliminating the job, such as the introduction of combine, which caused binders and threshers to become obsolete.

c. Conservation practices such as contour farming, grassed waterways and terracing.

C. Interest and fixed charges, including;

1. Cost of housing the equipment.

2. Insurance and taxes.

D. Annual repairs, including;

1. Cost of replacements.

2. Cost of labor (expert repair work).

3. Cost of labor (servicing).

4. Miscellaneous, grease etc.

E. Fuel and lubricants.

F. Operator's wages.

In respect to all these items of cost there are limiting factors which govern the working costs per acre or per hour.

1. The total crop area of a farm on which the tractor is used.

2. The total working hours of the tractor per year.

3. Changes in the cost rates of items constituting the working costs.

4. Necessary care of the machinery.

5. Efficiency of the operator.

A comparison of these items for a few tractors included in the 1947 survey will illustrate the differences in the various items of cost. These tractors were used on farms having from 40 to 160 acres of crops, and averaging 76 acres of crop.

Table 2:--TRACTOR COSTS BASED ON ACTUAL SURVEY, 1947.

Name of tractor	Make	New cost $	Total life years	Repair cost $	Depreciation $	Normal annual use hours: crop	Normal annual use hours: non-crop	1947 use hours: crop	1947 use hours: non-crop	H.P. Drawbar rating	Fuel per hours gal.
Allis Chalmers	B	760.	12	19	63.33	800	20	800	20	10.31	1.04
Case	S	1300.	12	30	108.33	1300	--	1300	--	16.18	1.35
Moline	RT	740.	10	140	74.00	1200	--	1200	--	15.66	1.69
John Deere	B	800.	15	200	53.33	500	120	500	120	19.04	----
Fordson	-	915.	15	25	61.00	400	---	400	---	12.80	----
Twin City	-	1385.	15	20	-----	400	---	200	---	15.98	----
Farmall	H	1200.	10	140	120.00	450	---	1500	---	19.14	1.7
John Deere	A	1350.	21	50	64.28	900	---	900	---	26.70	1.85
John Deere	B	900.	20	128	45.00	400	---	400	---	19.04	1.16
Farmall	H	1234.	10	7	123.40	700	120	1200	150	19.14	1.70
Total	10	10584	140	759	712.67	7050	260	8400	290	173.99	10.29
Average		1058.4	14	75.91	71.27	705	26	840	29	17.40	1.47

Percentage of different items of annual cost as related to new cost of tractor:

	Per cent
1. Depreciation = $\frac{100 \times 71.27}{1058.4}$ =	6.73
2. Repairs = $\frac{100 \times 75.9}{1058.4}$ =	7.17
3. Interest = 3.5	3.50
Total	17.40

It will be noted that the annual total for depreciation, repairs and interest amount to 17.4 per cent of first cost of the tractor. This might be compared with the 15 per cent used by Burdick (4) in calculating annual charges.

As shown in table 2 the farms under the study had one or more of the tractors mentioned there-in. There was a great variation in the cultivated area of the farms on which these tractors were kept. The age of the tractor directly affected the annual repair costs, which varied from $7.00 in case of new tractors to $200.00 in case of old tractors. The depreciation was directly proportional to new cost and the life of the tractor in years (estimated).

Table 3:--CALCULATION OF MACHINE COSTS AS PER TABLE 2 . (PER ACRE).

Crop acreage	Annual use in units per year (acres)						
	40	60	80	100	120	140	160
1. Costs related to crop area.							
A. Depreciation (average $71.27)	71.27	71.27	71.27	71.27	71.27	71.27	71.27
B. Interest, housing, insurance and taxes 7% of average or 3.5% of new cost = $\frac{1058.4 \times 3.5}{100}$	37.04	37.04	37.04	37.04	37.04	37.04	37.04
C. Animal repairs at $1.00 per crop acre	40.0	60.0	80.0	100.0	120.0	140.0	160.0
Total fixed cost $	148.31	168.31	188.31	208.31	228.31	248.31	268.31
Cost per acre or unit $	3.71	2.85	2.35	2.08	1.93	1.77	1.68

2. Variable costs related to time.

A. Fuel consumption per day 14.7 gallons @ 25¢ per gallon = $3.68.

B. Lubricants ¼ gallon per day (estimated) @ 80¢ per gallon = .20.

C. Operator's wages @ 75¢ per hour = 7.50

Total $11.38 or $1.14 per hour.

Similarly the hours of annual use differed according to the cultivated area of the farm on which a tractor was kept. Fuel consumption per hour had been taken as an average for different operations. Since different field operations require varying loads, there was a difference in fuel consumption per hour.

In calculation of machine costs per acre, there are two kinds of costs:

1. Constant; these include depreciation and interest because these two items are considered to be independent of the area of the farm, while the repair cost, though different on different farms, remains almost constant when reduced to area basis because the larger the area of the farm, the greater will be the total working hours and hence the higher the repair costs, or apprizimately in proportion to the acreage. But when these charges were calculated on acre basis, it was marked as per table 3 that where-as, the cost per acre on a 40 acre farm was \$3.71, it was only \$1.68 on a 160 acre farm. But there is a limit to the area which can efficiently be operated with one tractor. This limit is affected by the

   a. Nature of the crops grown.

   b. Amount of cultivation operations necessary for each crop.

   c. Actual calendar time available to finish a particular operation within the specific period to get the best and most economical results.

2. Variable : the every day running costs on the actual operation and the time or hours the machine is used. Since operating implements have varying width, they will cover a varying number of acres over a fixed time. The cost will therefore vary when reduced to per acre basis as per table 5 i.e. it took 1.64 hours for plowing and only 0.284 hours for harrowing per acre.

As shown in table 4 fuel consumption per hour as secured from the Colorado data was compared with the Nebraska test consumption at the rated load as well as at the varying loads. The fuel consumption at the varying loads was nearer to the farmers data on consumption as the tractors on farms actually operated were at varying loads.

II. Factors governing time requirements for different farm operations. To study the influence or significance of any one variable, it is necessary to keep other variables as constant as possible. In this study too, the results which indicated normal field operations conditions were taken. In actual field operations there are a number of limiting factors in time requirements, but many of these are minimized by having

Table 4:--COMPARATIVE FUEL CONSUMPTIONS AS SECURED FROM DIFFERENT SOURCES.

Name of the tractor	Make	H.P. Draw-bar rating	Average fuel consumption per hour		
			Colorado farm data	Manufactures specifications as per Nebraska tests	
				varying loads	rated loads
Allis Chalmer	B	10.31	1.04	.970	1.089
Case	SC	16.18	1.35	1.540	1.782
Farmall	A	13.11	1.26	1.077	1.363
Farmall	H	19.14	1.70	1.568	2.020
Farmall	M	26.23	1.94	2.165	2.495
John Deere	A	26.70	1.85	2.234	2.741
John Deere	B	19.04	1.16	1.561	1.928
John Deere	D	30.77	2.55	2.940	3.505
John Deere	G	27.08	2.20	2.500	2.872
Moline	RT	15.66	1.49	1.728	1.926
Oliver (row crop)	70	22.72	2.11	1.928	2.317
Total		226.94	18.65	20.211	24.058
Average		20.63	1.70	1.837	2.187

fairly average results from a number of farms of the same locality having more or less similar conditions. In this study four factors appear outstanding in governing the time requirements of particular operations.

1. The time required for servicing, rest and minor repairs during operations.

2. The time required for taking turns at the ends of the field.

3. Speed of the tractor.

4. Effective width of the machine.

For calculating the actual crew hours per acre, the following equation as formulated by Burdick (6), was used.

$$T = \frac{8.25}{SW}\left(\frac{1 + 16SN}{3L}\right) \quad (1 + A)$$

T is for time or crew hours per acre.

S is the speed of tractor travel in miles per hour.

W is the width of implement or machine used in feet.

L is the length of the field in rods.

N is the time required for turns at the end of the field expressed in fractions of a minute.

A is the time required for overall service and rest allowance expressed as a decimal figure, e.g. if a farmer estimates that he used 10 minutes per hour for A then A as expressed in decimals will be $\frac{10}{50} = 0.2$.

Another equation for finding out crew hours per acre was developed by Hertel and Williamson (12), 1941, to interpret their survey data.

Hours per acre = 100 ÷ (width in inches x miles per hour).

Hours per acre are the crew hours or the time taken in hours for cultivation of one acre.

Width in inches is the width of the implement or machine in inches.

Miles per hour is the travel speed of tractor in miles per hour.

The equation was perhaps developed to find straight time required for the cultivation of one acre, without making any allowance for time required for turns and other stoppages during actual working. In that case it is almost parallel to first part of Burdick equation as compared below:

$$\text{Hours per acre} = \frac{100}{\text{W in inches x S in miles per acre}}$$

(Hertel)

$$\text{Straight time} = \frac{99}{\text{W in inches x S in miles per acre}} = \frac{8.25}{\text{W in ft. x S}}$$

(the first term of the Burdick equation.

By simple mathematical calculation we find that an implement one inch in width will have to cover 99 miles to cultivate one acre and similarly an implement 12 inches wide will have to cover $\frac{99}{12}$ or 8.25 miles to complete one acre. For mathematical accuracy therefore, the figure 99 should have been in place of 100, but the figure of 100 was perhaps used to simplify calculation to some extent.

To illustrate the actual results, suppose a machine 60" or 5 ' wide was running at 4 miles per hour, what would be the calculated time according to the different equations?

$$\text{Hours per acre} = \frac{100}{60 \times 4} = \frac{5}{12} = .4166$$ (namely total time per acre according to Hertel).

$$\text{Straight time} = \frac{8.25}{5 \times 4} = \frac{1.65}{4} = .4125$$ (or straight time only, not total time according to Burdick).

Apart from the mathematical accuracy of first part of the Burdick equation, it also provides for the calculation of allowances of time almost essential in field operations, such as time for turns and time for service and rest, (the N and A of the Burdick equation).

In table 5 and 6 the farmers estimates as to total hours have been compared with the hours calculated by use of the Burdick equation under several sets of conditions. The farmers estimates of the value for use in the equation were not complete in all cases, hence the need for this form of interpretative analysis.

Table 5:--AVERAGE CREW HOURS PER ACRE BASED ON CALCULATION COMPARED WITH THE FARMERS ESTIMATE.

Machine or operation	Machine width in feet	Tractor speed in miles per hour	Crew hours per acre calculated on formula basis	Crew hours per acre A= 35	Crew hours per acre as per farmers estimate
Plowing	2.221	3.802	1.55	1.705	1.64
Eversman	11.25	3.61	.224	.352	.36
Float	11.16	3.736	.257	.338	.379
Harrow	14.13	3.85	.226	.265	.284
Spring tooth	18.80	3.336	.293	.361	.405
Sowing	8.23	4.04	.438	.485	.484
Ditching	7.18	3.94	.473	.51	.533
Cultivation	6.67	3.66	.567	.624	.757

Table 6:--CREW HOURS PER ACRE AS BASED ON DIFFERENT TIME FOR A WITH PERCENTAGE OF DIFFERENCE LESS THAN THE FARMERS ESTIMATE.

Machine or operator	Crew hours per acre with			Crew hours per acre as farmers estimate	Percentage differences less than the farmers estimate when			Average time for N used in calculation
	A=.1	A=.2	A=.35		A=.1	A=.2	A=.35	
Plowing	1.39	1.52	1.705	1.64	-15.2	-7.32	≠ 4.0	.592
Eversman	.207	.313	.352	.36	-20.3	-13.0	- 2.2	.5
Float	.275	.30	.338	.379	-27.5	-20.8	-10.8	.53
Harrow	.216	.236	.265	.284	-26.0	-17.0	- 6.7	.207
Spring tooth	.293	.32	.361	.405	-27.6	-20.8	- 0.85	.5
Sowing	.395	.431	.405	.484	-18.4	-10.9	- - -	1.0
Ditching	.416	.453	.51	.533	-21.9	-15.0	- 4.3	.615
Cultivation	.508	.555	.624	.752	-32.4	-26.2	-17.0	.65

Table 7, the tractor speed for specified gear ratios is compared with the actual speed as observed by the writer under field conditions. For sugar beet and potato harvesting operations the actual speed averaged 81.7 per cent of the rated speed, while for the other operations studied the actual speed was 92.5 per cent of the rated speed.

As noted in connection with table 5, the farmers estimates as to the specified speed of tractor were used in all calculations. This analysis of actual speed for a few operations suggests that the rated speeds reported by farmers were too high, which is another reason for the differences between calculated time and the farmers estimates of time.

By referring to table 5 it will be noticed that though allowance for time required for turns, servicing and rest etc, during field operation has been made, the crew hours so arrived at differ considerably from the farmers estimate. In case of plowing crew hours calculated with A = .35 exceed the farmers estimate, while in the case of sowing the two records almost equal each other. But in case of other operations the calculated crew hours even at A = .35 remain less than the farmers estimate, the highest variation being in case of floating, spring-toothing and cultivation.

Table 7:--TRACTOR SPEEDS PER HOUR AS PER SPECIFICATIONS AND ACTUAL FIELD RECORD.

Name of crop	Name of operation	Name of tractor	Model or make	Gear used	Speed as per actual record	Speed as per specification	Actual speed as percentage of specified	Actual time taken for turns in minutes
Sugar beets	Digging	Farmall	H	I	2.0	2.5		1.0
Sugar beets	Digging	John Deere	GM	II	3.16	3.5		1.0
Potato	Digging	Oliver	70	I	2.0	2.52		.75
Potato	Digging	Farmall	H	I	2.0	2.5		1.0
Potato	Digging	Farmall	H	I	1.88	2.5		1.0
				Total	11.04	13.52	81.7	
Sugar beets	Topping	John Deere	A	II	3.0	3.25		.5
Sugar beets	Trailer	Oliver	76	II	3.0	3.32		.5
Sugar beets	Defoliator	Ford	F	II	3.0	3.23		.5
Corn	Harvest	Farmall	A	I	2.14	2.25		1.0
				Total	11.14	12.05	92.5	

These variations have further been analyzed as per table 6 on the basis of three different time allowances for A and the differences given in percentage less than the farmers estimate. Here there are two sets of operations.

1. Operations where overlapping in actual operations was common, such as in the use of Eversman, float, harrow and spring tooth.

2. Operations in which there was no question of overlapping.

With A = .2 it was noted that the highest variation is in case of cultivation and lowest in plowing. The value of N as actually used in calculation had been shown against each operation. It was marked that N differed in some operations. Time up to 1 minute in case of sowing and only .207 in case of harrowing.

The actual speed records and the actual time for N shown in table 7 were secured from observations of the actual field work. These showed that the tractor actually traveled at about 7 per cent less speed than specified in easy operations and at about 18 per cent less in special operations, such as sugar beet and potato harvest. As regarding the time for N, it was noted that while the harvest operations were taking about 1 minute for turns only half a minute was taken in the lighter operations, also the tractor in light operations typically was working in second gear or at a higher speed.

It is now possible to review the factors which govern the time required per acre and to point out which factors appear to be signficant in their effects upon time and upon costs. As asked in the opening chapter "What are the limiting factors in the time requirements for different operations?"

These factors may be identified as follows:

1. Soil; the texture of the soil, its topography or slope may affect the speed of the tractor under the following conditions.

   a. Wheel slippage on light textured soil and steep slopes.

   b. Lowering of the speed in heavy or hard soil due to heavy draft and jerks.

   c. Wheel slippage and lower speed in stony and rough surface soil.

   d. Wheel slippage or slow speed in fields covered with more organic matter or humus.

2. Size and shape of the field. A long and rectangular field requires less running time per acre due to;

   a. Un-interrupted run of the tractor for a longer distance.

   b. Less total time in turns per acre.

c. No extra running necessary to go over the curves or angular spaces.

3. Width of machine. The wider the machine, the less will be the total time for turns and the actual operation per acre.

4. Possibility of combining operations or of overlapping. In a number of field operations, some overlapping has to be done to avoid gaps. The effective working width of a machine or implement will therefore be less than the actual width.

5. Time required for necessary servicing of the machine, rest and minor adjustments during the operations.

6. Time required for turns at the ends of the field.

7. Distance from farmstead to the field.

8. Unexpected breakage and delays.

9. Maintenance of machines.

10. Care of working machines during operation.

11. Efficiency of operator.

In addition to these general factors, it is apparent that there are errors in the estimates made by farmers as to the conditions under which the field work is done. The more important of these errors as found by the personal observations of the writer are:

1. The farmer may not be precise in estimating the hours that the tractor was actually working.

2. Actual area covered may be inaccurately estimated, if it is a part of one big field.

3. Overstating the hours for actual operation of equipment.

4. The acreage covered per day is usually rounded to the acre.

From all the items just listed, four stand out as being most important in their effects upon time per acre, namely:

1. Speed of the tractor.

2. Width of the machine.

3. Time required for servicing and rest etc. or A.

4. Time required for turns at the ends of the field or N.

Out of these variables number 3 or A was given certain constant value in making the calculations for this study in order to permit analysis of the other variables.

There now remained two variables i.e. speed of tractor and width of the machine.

To study the effect of speed records were collected on the actual working speed of tractors as shown in table 7. These showed that a variation in speed from 7.5 to 18.3 per cent could be expected.

With these findings we now turn to table 6 and analyze the differences between equation calculations and farmers estimate for certain operations.

1. Operations in which there is no overlapping of machine.

a. Plowing; after making an allowance of A= .2 and N = .592 minutes, there remained a difference of 7.32 per cent less for the calculated time compared to the farmers estimate.

b. Sowing; after an allowance of A = .2 and N = 1.0 the calculated time remained 10.9 per cent below the farmers estimate.

c. Ditching; after an allowance of A = .2 and N = .615 minutes there remained a difference of 15 per cent.

d. Cultivation; with an allowance of A = .2 and N = .65 minutes there remained the difference of 26.2 per cent.

In summary the calculated time varied from 7.32 to 26.2 per cent below the farmers estimate.

2. Operations in which overlapping is necessary.

a. Eversman; with an allowance of A = .2 and N = .5 minutes the calculated time remained 13 per cent below the farmers estimate.

b. Float; after an allowance for A = .2 and N = .53 minutes the difference remained 20.8 per cent below the farmers estimate.

c. Harrow; after an allowance of A = .2 and N = .207 minutes the difference remained 17 per cent.

d. Spring-tooth; with a common allowance of A = .2 but N = .5 minutes the difference remained 20.8 per cent.

In summary the calculated time in these operations varied from 13 to 20.8 per cent below the farmers estimate.

These differences are due to errors in the data secured as to the working speed of tractors, the effective width of machines and errors in the farmers overall estimates of the necessary time for an operation, or as to the time required for turns or for service and rest. In all these cases it would be possible for an experienced investigator, once he was aware of these sources of error, to secure accurate field observations in future studies to avoid similar errors.

Summary

This study has given significant clues on the following points:

I. Working costs of tractors.

A. Constant costs.

1. When reduced to per acre costs on the basis of the area of the farm on which a tractor was maintained, there was a great range of variation. The cost per acre on a 160 acre farm could be reduced to less than half of the cost at a 40 acre farm, i.e. $1.68 in comparison to $3.71.

2. Constant items of cost in terms of percentage of new cost:

a. Depreciation	6.73
b. Interest	3.50
c. Repairs	7.17

B. Variable costs per hour were $1.14 with prices used.

C. The fuel consumption per hour in gallons was much less than the consumption at the Nebraska tests for Rated loads, i.e. about 78 per cent, but was nearer to the per hour consumption at varying loads, as shown by the Nebraska tests.

II. Farm operation time costs.

A. Time requirements for field operations.

1. The time per acre for plowing estimated by the farmer was 1.64 hours, and for that of harrowing only .284 hours. Tractor costs for these operations will therefore greatly differ

on per acre basis.

2. Crew hours when calculated with A = .35, came much nearer to the farmers estimate of time than the crew hours calculated with A and N, as per farmers information.

3. By reducing the calculated crew hours with different allowances for A and finding out the percentage of difference, i.e. less than the farmers estimate, it appeared that with A = .2 the results appeared more reasonable than either with the allowances of .1 or .35 except in the case of cultivation and ditching, but in these cases time for N was .65 and .615 respectively where-as it was 1.0 in case of sowing.

4. The speed of tractors in actual field work was less by 7.5 to 18.3 per cent than the specified speed.

5. Taking time for A = .20, the resultant differences in time were estimated to be due about 5 to 10 per cent to slow speed and about 5 to 10 per cent due to overlapping.

Chapter V

DISCUSSION

As outlined in previous chapters, six questions arose out of the problem analysis. These were therefore discussed in the same order.

I. What items constitute the working cost of equipment? Under analysis of data, these costs were enumerated to consist of:

A. Depreciation due to wear. Mechanical deterioration of life time wear is affected by;

1. Amount of use.

2. Operating conditions.

3. Care by operator as to lubrication, adjustment, repair and shelter.

B. Obsolescence. This is brought about by one or more of the following reasons;

1. Many tractor mounted tools made especially for one make of tractor becoming obsolete when their tractor becomes obsolete, regardless of their own condition.

2. New inventions and changed farming practices making a machine obsolete. Some of

these items are;

a. Increased efficiency of new machines doing the same job.

b. Development of new methods eliminating the job.

c. Changes in farming practices, such as contour farming, grassed water-ways and terracing in connection with soil conservation.

C. Interest and fixed charges.

1. Cost of housing the equipment.

2. Insurance and taxes.

D. Annual repair costs including;

1. Cost of replacements.

2. Cost of labor (expert repair work).

3. Cost of labor (servicing).

4. Miscellaneous, grease etc.

E. Fuel and lubricants.

F. Operator's wages.

The committee on farm machinery under "Rental rates for farm machinery" (21), 1943, considered the following points for calculation of machine costs.

1. Depreciation on straight line basis.

2. Charges for interest, housing, taxes and insurance.

Similarly Starch (25), 1933, Davidson and Henderson (11), 1942, Richey (22), 1942, Morrison and Baumann (16), 1942 and Burdick and Pingrey (6), 1929, discussed one or more items of working costs in connection with their different studies.

The costs under depreciation and annual repairs as based on survey data are shown in table 2. The depreciation cost came to 6.73 per cent. If this figure is taken as a basis for depreciation on straight line basis, the working age or life of wear of a tractor would be $\frac{100}{6.73} = 14.86$ years. The annual use hours as shown in the same table were 731. The average working life (hours of use) of different makes of tractors detailed in table 2 was therefore 10,863 hours while according to the total life in years in the same table, the average life came to 14 years. On this basis the average life would be 10,234 work hours. Similarly the interest including the cost of housing the equipment, insurance and taxes was calculated at 7 per cent of the average cost or 3.5 per cent of the first cost.

The average annual repair cost of $75.90 was 7.17 per cent of the average new cost. The average area of the farms on which these tractors were maintained was 76 acres. By calculating the above three costs on per acre basis as shown in table 3, the cost per acre at a

40 acre farm is \$3.71, at a 80 acre farm, \$2.35 and at 160 acres \$1.68, in other words, for every reduction by half in the area of the farm, the cost increased by about 50 per cent per acre.

Since the cash costs calculated by previous investigators were based on specific studies, where the working life of the machines had influenced the depreciation costs, amount of use and condition under which used, the repair costs and the market rates of fuel and oil, the running costs, the comparison of such figures will not offer a satisfactory basis. For this purpose therefore, the basic data were compared.

Under similar studies made by Richey (22), 1942, the depreciation was calculated on the basis of tractor life of 15 years with 500 hours of annual use i.e. a total of 7500 work hours to wear out and total repair cost of 35 per cent of new cost. Interest, housing, taxes and insurance were charged at 4.0, 1.0, 1.6 and 0.4 per cent on average investment cost respectively, making a total of 7 per cent.

The committee on farm machinery under their studies Rental rates for farm machinery (21), 1943, based their calculations of depreciation on 7500 working hours of life of a tractor with 500 hours of annual use and 35 per cent of new cost as the total repair cost, and the interest, housing, taxes and insurance at 7 per cent of the average cost.

Burdick (4), 1943, in his studies for calculating the rental charges for farm machinery charged an average cost of 15 per cent of the new cost, to include depreciation and interest including housing, taxes and insurance, cost of annual repair and allowance by way of remuneration to the owner of the machine. According to his calculation of working costs on an acre basis, the working cost per acre on a 40 acre farm was double that of the cost per acre on an 80 acre farm. The following table compares certain studies.

Table 8:--BASIC FIGURES USED FOR CALCULATION OF CONSTANT COSTS OF TRACTORS.

Study reference	Basic life in years	Use per year hours	Total lifetime repair cost % of new cost	Annual interest rate including housing, taxes and insurance based on average cost
				Per cent
1. Richey (22)	15	500	35	7
2. Rental rates for farm machinery (21)	15	500	35	7
3. Kalbfleisch (13)	15	500	30	6
4. Present studies	14	731	7.17 (annual)	7

Davidson (11), 1942 and Burdick (4), 1943, in their respective studies calculated the total annual costs in per cent of new cost. According to Davidson, these costs were 12 per cent of new cost, while Burdick calculated these costs at 15 per cent of new cost. From the above table it will be noted that the basic life in years for the tractors in this study was less by one year as compared to the other reports, while the annual use in hours was about 50 per cent higher. The annual use was perhaps affected by the fact that the data pertains to irrigated farming area where farming is more intensive than in the un-irrigated area. The comparatively more use per year had also affected the annual cost. Moreover, as shown in table 2, four tractors out of ten had substantially higher repair costs, otherwise the repair costs in case of the remaining tractors were almost the same as mentioned by various authors.

The day to day working costs of tractors i.e. fuel and lubricants are tabulated in table 2. The average draw-bar horse power was 17.4 and the average fuel consumption was 1.47 gallons per hour. These figures were used in calculating the per day working costs of tractors. The lubricants at ¼ gallon per day were used as an estimated quantity. The fuel consumption was compared with fuel consumption in Nebraska tractor test detailed in the Red tractor book (20), 1948, for the tractors included in table 2 and other tractors as shown in table 4. The average fuel consumption of 1.7 gallons per hour for tractors of 20.63 D.B.H.P. was nearly equal to the consumption given in Nebraska tests at varying loads.

Morrison and Baumann (16), 1942, in a similar study, stated that the average fuel consumption for general purpose two-plow tractors was 1.3 gallons per hour and oil, 1.5 quarts per 10 hours. In another study made by Mumford (17), 1942, it was found that the fuel consumption for tractors having 14-17 rated drawbar horse power was 1.94 gallons per hour. Since this consumption was at the rated load, it should be reduced 75 per cent for average consumption at varying loads. At varying loads, therefore, it was about 1.46 gallons per hour.

Kalbfleisch (13), 1943, during his studies found that a 2-3 plow, 14-20 D.B.H.P. tractor consumed 1.0, 1.4 and 1.8 gallons of fuel in light, medium and heavy work respectively. Comparative results are shown in table 9.

From table 9 it was marked that the fuel consumption per hour was more or less directly properional to D.B.H.P. and results, when compared on this basis, were almost parallel. As regards the working cost on account of operator's wages, this has perhaps been charged by various investigators on the basis of the prevailing rates in the locality at the time of

Table 9:--COMPARATIVE FUEL CONSUMPTION PER HOUR FOR TRACTORS.

Study reference	Tractor class	Drawbar H.P.	Average fuel consumption per hour	Oil per day quarts
1. Morrison (15)	2-plow	about 14	1.3	1.5
2. Mumford (17)	2-plow	14-17	1.46	----
3. Kalbfleisch (13)	2-3 plow	14-20	1.40	----
4. Present studies	various classes	17.4	1.47	1.0

making such studies. The prevailing wages for tractor operators in the vicinity of Fort Collins for these studies were then 75 cents per hour, and this rate therefore was used in calculating costs in the present studies. Similar was the case for rates of fuel and oil.

Referring again to the introduction and the statement of the problem, there are two questions which must be kept constantly in mind: "What are the limiting factors which govern such costs?" and "How can the cost under each be lowered?"

A. The cultivated area on which a tractor is maintained. If a tractor is maintained at a farm, where it can be used to its optimum capacity in doing different jobs at the farm, the cost per acre can be greatly reduced, for example if a tractor has sufficient D.B.H.P. to pull an implement 6' wide or for developing higher power at the pulley but it is not put to that use, the output per hour will decrease and the cost per work unit will increase. In the interest of reducing the cost to the minimum efficient point, it would be necessary either to purchase the equipment actually required for the farm or to increase the cultivated area by one or more of the following ways.

1. Renting more land according to the capacity of the equipment.
2. Cooperative use of equipment.
3. Share ownership of equipment.
4. Hiring the work required for certain operations.
5. Exchange and borrowing of equipment.

B. The total working hours of the tractor per year. By increasing the economic use of a tractor to more hours per year, the costs under depreciation and interest per working hour will lower proportionally, but the total cost under repairs will increase somewhat. Increasing the working hours of a tractor also means increasing the cultivated area discussed under A above, but this can also be achieved by adapting different combinations of farm practices, e.g. a tractor can be used for working silage machines, dairy plant or temporary workshop plants and hauling of other farm products from one place to another, in other words, the use for jobs other than the actual field work. Here it can be said that if we increase the use per year, the total years of life will decrease somewhat. This point is fully illustrated by actual data in table 2 and compared in table 8. It will be seen that with a little extra cost on annual repairs the annual use was 50 per cent higher and the total life was reduced by only one year; in other words, the total working hours were increased from 7500 to 10,234 reducing per hour costs under depreciation and interest. Again every machine has a certain time limit for efficient and economical use, after which it requires higher repair costs as the metallic parts start corroding. The cost per hour can, therefore, be reduced by using the equipment in one or more of the ways enumerated above.

C. Necessary care of the machinery and the efficiency of the operator. Though these are two separate items, they are inter-related as a machine well-cared-for and kept in good condition, adds to the working efficiency of the operator, similarly an efficient operator is supposed to keep his machinery under the best working order. This item will be discussed fully in connection with field operation requirements.

Schwantes (23), 1934, Davidson (10), and Burdick (6), 1947, included the above points as limiting factors to explain their findings on working costs of tractors and other equipments.

We now turn to the next question raised in the introduction i.e. "What are the limiting factors in the requirements for different operations?"

As already explained under analysis of data, the main factors affecting field operation time requirements appeared to be:

A. Soil in regard to its texture, slope and topography, which could directly affect the tractor speed, either through the wheel slippage or by controlled and lower speed due to one or more limitations of the above factors.

B. Size, shape and length of the field can bring about economy in total working time per acre in one or more of the following ways.

1. Cultivation equipment requires less running time per acre in the following ways;

a. Un-interrupted run of the equipment for a longer distance.

b. Less total time in turns per acre.

c. Extra running to cover curves and angular spaces is not necessary.

C. A comparatively wider machine will take less total time both for turns and per acre.

D. The degree or amount of overlapping of certain implements in field operations, affect the effective width of the implements and consequently the total time per acre.

E. Time for necessary servicing of the machine, rest and minor adjustment during the operations is found to be a very important and major item in actual field operations.

F. The time for turns is directly dependent on the length of the field and the efficiency of the operator in regard to the speed of the tractor at the turning points.

G. Maintenance and upkeep of the machines to keep them in the best working conditions.

H. Handling and care of working machines during operations. This is directly connected with the efficiency of the operator.

Out of the above items the time factor appeared sigificant under:

A. The slippage of wheels or slower speed of the tractor.

B. The degree and amount of overlapping of implements in certain field operations.

C. Time necessary for servicing of machines, rest and minor adjustments during actual operations.

D. Time for turns.

In the present study these time factors were measured to a certain extent by analysizing the actual survey data and other observations.

Burdick (5), 1947, in a similar study also considered the above factors, which affected the time requirements for field operations, and measured these under items E and F alone i.e. the time necessary for servicing, rest and unknowns and time for taking turns at the end of the field.

The next question raised in the introduction was "What differences in cost per acre are secured by different methods?"

Here again the per acre cost will depend on the degree of influence of each limiting factor. It was therefore necessary to study the influence of the outstanding factors. Since all the factors are so closely inter-related, that it will be almost impossible to allocate specific time for each factor. The factors having outstanding influence and which could be measured in actual field work to a certain degree were considered. The main problem, therefore, arose to find out the actual details of the machinery or implements used in certain operations and the time actually taken to do the operation on one acre. For this purpose data secured in 1947-48 from farmers on irrigated farms in Weld county, Colorado were analyzed using the farmers estimate as to machine width and speed of travel. The straight time necessary to complete one acre was calculated by using the first part of the Burdick equation. By observation it was found that sufficient time is lost in taking turns and other stops and hence a longer total time per acre is necessary. The information on factors, causing delay in field operations was also collected from the farmers, wherever possible. Wherever such information was not recorded, the information formulated by Burdick (5), 1947, in his studies for N (time for turns) and A (time for servicing, rest and unknowns) was used i.e. 0.5 minutes for N and 0.33 for A. The data calculated on this basis for crew hours per acre was tabulated and averages for a number of normal operations under each head were taken as shown in table 5. To measure the influence of other variables, a constant time for A = .35 was taken. It was then compared with the average of crew hours on each operation which the farmer estimated. From the figures shown in table 5 it was noted that the crew hours calculated for plowing exceeded the farmers estimate, but were almost equal in the case of sowing, and were less in other operations. It therefore, gave a clue that there were more significant factors other than N and A and at the same time it indicated that the time factors allowed in case of plowing and sowing were perhaps more than the time the farmers actually took. To have a clearer picture the data were further analyzed as shown in table 6. The average time allowed for N in the actual calculations was also noted in the same table. The calculated crew hours per acre were then calculated with A = .2 and A = .1. By looking at the percentage differences it was found that crew hours with A = .2 were less by 7.32 per cent in case of plowing and about 26 per cent for cultivation as compared to farmers estimates.

Assuming A = .2 and the time for N as noted against each item, the next two outstanding factors likely to affect the crew hours could be;

1. The slippage of wheels in field work.
2. Amount of overlapping of certain implements.

To apportion the time likely to be taken by each of the above two factors, the items or operations detailed in table 6 were grouped in two distinct divisions.

a. Operations in which overlapping is not usually done. These being plowing, sowing, ditching and cultivation in the present study.

b. Operations in which overlapping is usually done. These being the use of such machines as eversman, float, harrow and spring tooth.

In the case of operations where overlapping is not done the only significant factor for increased time might be wheel slippage. To measure the probable effect of this factor, time records were made for tractor speed in field work as per table 7. It gave a basis for the assumption that the tractor speed in the field work was slower than the specified speeds. This, apart from wheel slippage, may, to some extent, be due to lowering the speed by use of the clutch to keep the tractor speed well controlled for special work like interculture or cultivation in standing crops sown in rows. This difference as per table 7 varied from 7.5 to 18.3 per cent according to the nature of operation.

With this assumption in view, if we now look to table 6 and note the time difference with A = .2, the per cent difference in case of plowing and sowing ranges between 7 to 11. The difference in case of ditching and cultivation was 15 per cent and 26.2 per cent respectively. The higher difference in case of cultivation was perhaps due to frequent use of clutch to keep the speed well controlled to go straight in between the rows of standing crops. From the above figures it was evident that a difference in speed due to wheel slippage might be about 10 per cent.

With this presumption in mind, we now turn to operations where certain amount of overlapping has to be done to avoid uncultivated gaps. This factor could not be measured accurately in the field, because it is very difficult to move a tractor in a straight line, so the amount of overlapping cannot be constant, but from the observations in the field, it was noted that about one foot of the implement has to be allowed for overlapping to avoid gaps. As shown in table 6 the per cent difference range was from 13.0 in case of eversman to 20.8 in case of float and spring-tooth. The average width of these implements as shown in table 5 varied from 11.16 ft. to 18.8 ft. and assuming an overlapping of about a foot to a foot and a half, it could be estimated as about 10 per cent of the actual width of the implement. In case of these operations it could then be assumed that both the factors i.e. slippage of wheels and overlapping of implements could probably be responsible for a difference of about 10 per cent each.

Other authors too, calculated the influence of time limiting factors in field operations during the course of their various studies. In his studies, Starch (25), in 1933 analyzed the factors of production, to determine the lowest cost method of organization and found the following results:

1. Percentage of actual field work to the total time in case of plowing varied from 75 to 92 per cent.

2. The differences in percentage between total reported time and the actual working time were;

a. Plowing (in stony ground)	18-22%
b. Seeding and combining	26-38%
c. Disking, duck-footing and harrowing	11-22%

In another study made by Stippler (26), 1944, it was stated that acreage for plowing reported by farmers was 84 per cent for plowing and that for harrowing 76 per cent of the acreage calculated.

Burdick (5), 1947, in a similar study on field cultivation records analyzed the effects of N and A in time requirements for field operations and indicated that the average time for N was about $\frac{1}{2}$ minute, whereas the time for A varied from 20 to 35 per cent. The results are compared in the following table.

The results of the present studies were quite close to the findings of Starch (25) and Burdick (5), but a little higher than the findings of Stippler (26).

The foregoing factors must therefore be accounted for, when calculating the actual crew hours

Table 10:--COMPARISON OF CALCULATED TIME WITH TIME REPORTED BY FARMERS IN CERTAIN OPERATIONS.

Study reference	Field operation	Time differences in per cent	Remarks
Starch (25)	Plowing	8-25	Differences in % between total and actual working time
	Plowing (stony ground)	18-22	
	Seeding	26-38	
	Harrowing	11-22	
Stippler (26)	Plowing	16	Expressed in terms of acreage percentage in studies
	Harrowing	24	
Burdick (5)	Operations in general	20-35	Overall service and rest allowance $\frac{1}{2}$ minute for N
Present studies	Operations in general	20	Overall service and rest allowance
		5-10	In tractor speed
		5-10	Overlapping

necessary for formulating a scheme for finding out an equipment and area combination or calculating the cultivation costs. The next question from the introduction was: "How far can these differences be overcome through efficient management?"

To answer or analyze this question, we have to refer back to question four i.e. what are the limiting factors in time requirements for different operations and consider them according to the degree and kind of their limiting influence. The first of these being, soil in regard to its texture, slope and topography. This factor is a permanent limitation so far as field operations are concerned. The second factor is size, shape and length of the field. This factor may not be eliminated altogether, but can be modified by proper layout of convenient sized fields for the most economical use of the power equipment. The third point is the width of the machine. This too, is almost a permanent limitation because the width and size of the equipment are selected by the farmer somewhat in relation to the size of his farm. The fourth limiting factor is the degree or amount of overlapping. From the analysis of data it was found that it affected the total working time from 5 to 10 per cent. An efficient operator can reduce this item by at least half thus saving possibly 5 per cent. The fifth factor is in fact the major item for time requirements of field operations. It is the time necessary for servicing of the machines, rest and other adjustments during field operations. The time required for these items can be reduced by:

1. Replacing old and worn out equipment for better efficiency and long run economy.

2. Keeping the machinery in a good working condition by giving a little more attention during off time and putting the machinery to its best use according to its capability.

3. In addition, that part of the "service allowance" which is required by the individual for his personal rest is subject to much variation. Many studies in industry have shown that at least 20 per cent should be added to all other time for human needs. However, an efficient, energetic operator can reduce this temporarily or during rush seasons. There will still remain an absolute minimum of time for greasing and adjusting the equipment.

The next factor is the time necessary for turns at end of the field as illustrated in table 7. It varied from $\frac{1}{2}$ to 1 minute. This can be reduced in two ways:

1. By having long and rectangular fields, of course in accordance with other limiting factors.

2. By having full working control in using the equipment.

The remaining two items regarding maintenance or up-keep, handling and care directly depend on the efficiency of the operator.

After analyzing the foregoing six questions under Problem Analysis, we detail the significant facts to answer the main problem; namely, the requirement for efficient use of mechanical equipment in crop production.

Tractor working costs: constant costs comparing the depreciation, interest and repair costs;

1. These could be reduced to the minimum possible point by adjusting a well balanced land and equipment combination. These costs analyzed in table 3 showed that where-as the cost on per acre basis was $1.68 at a 160 acre farm, it increased to $3.71 on a 40 acre farm and was $2.35 on an 80 acre farm i.e. every reduction in area to half increased the per acre costs by about 50 per cent.

2. During the same studies it was found that the area of the farm per tractor varied from 40 to 160 acres, with an average cultivated area for the farms under study of 76 acres as per table 3.

3. The average life of tractors at the farms under study as per table 2 was estimated to be 14 years with an annual use of 731 hours.

4. Constant items of cost in terms of percentage of new cost;

	per cent
a. Depreciation	6.73
b. Interest	3.50
c. Repairs	7.17

Tractor working costs: variable costs;

1. The average fuel consumption of tractors with an average of 17.4 D.B.H.P. was 1.47 gallons per hour as per table 2, and is fairly comparable to fuel consumption arrived at by various investigators in their different studies.

2. The per hour consumption of tractors in the study was on the average of about 78 per cent of the fuel consumption at rated loads as noted in the Nebraska tractor tests, table 4.

3. Working costs at 25 cents per gallon for fuel, 80 cents per gallon for oil and 75 cents per hour for the operator's wages, came to $1.14 per hour for about 17 D.B.H.P. class tractors.

4. These costs could be effectively reduced by using the tractor at its optimum load in any of the following ways;

a. Purchasing a tractor with its standard equipment.

b. Combining certain field operations.

c. Checking the carburator and spark plugs regularly and keeping them well cleaned and adjusted.

Farm operation time requirements have the following major limiting factors:

1. Slower speed of tractors in field work than the specified speed. It varied from 7 to 18 per cent under speed observation, as per table 7, but was estimated to affect the average in data analysis from 5 to 10 per cent as per table 6. The slower speed being either due to wheel slippage or using the clutch too often, can be improved by a well trained operator as he can minimize the use of clutch by better control of steering for straight driving.

2. Overlapping necessary in certain field operations. The efficiency of operator with better steering control can reduce the time under this head by reducing the amount of overlapping. In analysis of field records as per table 7, it was considered that this factor might have affected the total time requirement from 5 to 10 per cent.

3. Overall time for servicing of machine, rest and necessary adjustments during field work. By adjusting the time for A at 0.1, 0.2 and 0.35, table 6, it was noted that an overall allowance of 0.2 or 20 per cent of the working time was considered to be the average time taken under this factor. As discussed before the time for servicing as per manufacturers guide is essential, but the time under rest and necessary adjustment can be reduced to a great extent by keeping the machinery in good working

order and looking to proper adjustment during off time.

4. Time for turns at ends of the field. The average time for this item used in data analysis was based on records. It varied from 0.2 to 1 minute per turn, as per table 6. After noting the time too, as per table 7 it was found that it varied from 0.5 to 1 minute. It was noted that N was larger for general operations requiring more care at the ends of the fields, such as sowing, digging and cultivating.

Other limiting factors in time requirements are:

1. Surface texture, slope and topography of the farm land.

2. Size, shape and length of the fields.

3. Width of the machine with reference to the number of turns necessary per acre.

4. Maintenance and up-keep of the machines.

5. Handling and care of machines during operations.

6. Efficiency of the operator.

The above factors, individually or collectively, do affect the total time of field operations, but this influence could not be measured effectively for precise statement.

The present study and analysis of data indicated a number of side issues, which require further investigation for precise results.

Suggestions for further study are:

1. To find out the best combination of land and equipment to reduce the working costs to the most economical point.

2. To study the relation of repair costs to the total working life of equipment.

3. Further investigation and analysis of field survey data for more precise results on wheel slippage of tractors and overlapping of implements.

4. Investigations for suggestions to farmers for optimum use of tractor power and its working life.

Chapter VI

SUMMARY

Among the items compared in this study of the cost of cultivation of farm crops, usually nowadays it is found that the major element is the machine and equipment costs. To have a clear idea of these costs, the present studies were made on farm machines. The problem under investigation was to find out the requirements for efficient use of mechanical equipment in crop production. To answer the main problem the items which constitute these costs were analyzed, under the following heads:

1. Items that constitute working costs of equipment.
2. Limiting factors governing such costs.
3. Possibility or methods necessary to reduce such costs.
4. Limiting factors in time requirements for different operations.
5. Differences brought about by the limiting factors in various operations.
6. Possibilities of overcoming such factors through efficient management.

For this study data secured in 1947-48 from farmers on irrigated farms in Weld county, Colorado were analyzed and compared with:

1. The data secured from the representatives of farm machinery companies.

2. Published data in certain experiment stations and technical reports.

3. Personal observations.

The data were analyzed on the basis of the Burdick equation to find out the crew hours per acre to compare it with the time as per farmer's estimate. The equation used has been explained in the preceeding chapters and is published in the Colorado Agricultural Experiment Station, Colorado A. and M. College, Fort Collins Technical Bulletin 36, June 1947. The speed of the tractor was used as specified by tractor firms and width of the implement was the actual width. The same data for the entire farms were used for sorting out the tractors in regard to the cost, depreciation, repairs, working life of the farm equipment and fuel consumption of different tractors. Data for tractors as given by manufactorer's were taken from the "Red Tractor book", 1948. Implement and tractor, Kansas City, Missouri while the personal observations were recorded in the field for tractor work.

The present study covered two aspects of machine costs and time requirements for different operations as enumerated before: factors governing working costs of equipment, especially tractors and factors governing time requirements for different operations.

The first included the following items and the results derived from the present study were as under:

1. Depreciation. The average working life of tractors studied was found to be 14 years with an average annual working hours of 731 or about 10,000 working hours and was 6.73 per cent of present cost.

2. Interest. It was calculated at 3.5 per cent of the first cost and included cost of housing, taxes and insurance.

3. Annual repair costs. These varied in case of different tractors according to their age and present condition. The average repairs were found to be 7.17 per cent of the average present cost.

4. Fuel and oil. The average fuel consumption for an average 17.4 D.B.H.P. class tractor was found to be 1.47 gallons per hour.

5. Operator's wages. These differed considerably in different places. The cost of working an average 17.4 D.B.H.P. class tractor at 25 cents per gallon for fuel, 80 cents per gallon for oil and 75

cents per hour, came to $1.14 per hour.

The second included a number and variety of factors. The outstanding ones, which could be measured to a certain degree are enumerated below.

1. Actual tractor speed in field work. By taking time observations and then analyzing the data, it was marked that the speed in field work was slower than the specified speed. In observations it varied from 7 to 18 per cent, but according to the analysis of survey data, it was estimated that its influence might have been 5 to 10 per cent.

2. Extra time necessary for overlapping of certain implements in field operations. Though it was not possible to measure effectively the effect of this factor, the analysis of field work records gave a clue that this factor had a considerable influence which was estimated to be from 5 to 10 per cent on the total working time.

3. Overall time necessary for servicing, rest and adjustments, sufficient work has been done by previous authors on this factor and as much as 35 per cent of the working time had been accounted for this item. Under the present studies it was estimated to be about 20 per cent of the working time.

4. Time for taking turns at the end of the

fields. This greatly depended on the nature and size of the machinery used and the efficiency of the operator. By taking records in the field it varied from 0.5 to 1 minute per turn according to the type of the machinery used. On the average a time of 0.5 minute per turn appeared most significant.

A P P E N D I X

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Appendix A.--SAMPLE OF CROP

CULTIVATION DATA, FORM A

State

Crop cultiva

Date of Operation	Machin or Operat
A	B
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

State ____________ ____________ County ______________ Farm ______________ Area:-Total __________ Cropped __________

Crop cultivation data. For: ______________ Acres ______________ Width of Row __________

Date of Operation	Machine or Operation	Width of Machine		Acres Covered	Crew hrs. as per farmer's record	Number in Crew and Power											Average length of row (rods)	Minutes per turn	Min. per hour for rest & service	Remarks
		Actual	Effective			Men	Tractor									Auto or Truck				
							Kind	Model	Drawbar h.p.	Kind of wheels	Gear	Speed miles p.h.	Kind of fuel	Gals. per day or per operation	Oils and grease per day					
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
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Appendix B.--ORIGINAL DATA ON FILE

IN OFFICE OF ECONOMICS AND SOCIOLOGY

B I B L I O G R A P H Y

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