

FARM MACHINERY SELECTION:
A LINEAR PROGRAMMING MODEL

by

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CHAPTER I

INTRODUCTION

One of the most complex problems facing farmers is that of machinery selection. Many factors affect this decision including total acres, acres of each crop, weather conditions, tillage practices, timeliness of operations, costs of production and prices received for the agricultural product. The effect of any one of these factors on profit can be of considerable importance. The farmer needs to consider all of these factors simultaneously if he expects to realize the maximum potential profit with the existing set of resources.

Weather is one of the most important factors affecting size of machinery required, as it determines the amount of time available for field operations. Only recently has significant work been done to determine, from meteorological data, the time available for field work during a specified time period. This information gives the basis for machinery selection which previously was left to the farmer to supply, or was based on rough estimates.

Timeliness of field operations affects the yield of crop production. Each crop has a unique time period for planting, harvesting, etc., which results in the highest yield. In order to get all operations completed during the 'optimum' time period, given the time available for work during that period, a certain machinery size is needed.

There is a complex set of interrelationships among economics, biological and physical factors which determine the right size of equipment for a given farm operation. Prices, crop yield, cost and type of

inputs and the labor required influence mix of crops. If labor is limited, then the crop with the highest return per acre may not be the most profitable crop with respect to labor use and availability. When the previously mentioned factors are considered individually, an estimate of the optimum machinery size required, is feasible; but when all those factors are considered simultaneously, the result is not readily apparent and the interaction is so complex that a systematic approach is needed to find the most profitable situation.

OBJECTIVE OF THE STUDY

The objective of this study is to develop and test a linear programming model for northeast Kansas cash-grain farms, that simultaneously select the most profitable size of machinery, combination of crops and tillage practices. Choice of machinery, crops and tillage activities is based on the amount of land, labor and field workdays available.

CHAPTER II

REVIEW OF THE LITERATURE

One of the more difficult tasks confronting farmers is the selection of the proper size of farm machinery. There are many aspects of the farm which must be considered, including total acreage, combination of crops, tillage practices and time available for field operations.

In 1967, Donnell Hunt developed a Fortran computer program for selection of farm machinery. (14) This program calculates the amount of power necessary to perform the farming operations required. Using a power factor for different types and sizes of machines in combination with their costs of operation, the optimum combination of machinery size, tractor units and size are determined. The program requires that you specify the acreage of each operation to be performed, e.g. 100 acres of plowing wheat, 200 acres of discing sorghum ground, etc. No specific amount of time is allowed for these operations by the program, however, each implement has a 'timeliness' factor associated with it. (14) The smaller the implement the larger the timeliness factor, resulting in a greater penalty for use of small implements. This program does not allow for finding the optimum mix of crops, which is an important factor in determining the maximum net income from a given set of resources. It is the object of the Hunt program to minimize costs given a certain set of crop acres and tillage practices.

Work done by Smeidler at KSU dealt with Hunt's program making it a more workable model and more general in its application. (21) The major changes or additions to Hunt's program, by Smeidler, include:

1. Construct a more precise annual cost equation by utilizing equations employed in Hunt's program to express the cost factors of all implements.
2. Increase the utility of Hunt's program by allowing a different fuel type for each engine in the farm machine system.
3. Include in Hunt's program information available in the Agricultural Engineer's Yearbook concerning:
 - a) energy needed for equipment driven by the PTO shaft of the tractor or an engine, and
 - b) tractor drawbar performance.
4. Improve Hunt's program by
 - a) making use of optimizing techniques used in management science, and
 - b) redesigning the program as a set of subroutines. (21)

Although Smeidler's work provides a more workable model within the framework of Hunt's original program, the model still has rigid characteristics. These include requiring the mix of crops to be given by the user and retaining the 'timeliness' factor associated with each implement.

A linear programming model, developed at Purdue University by the Department of Agricultural Economics, has culminated in what is called Model B-9. (6) The model consists of three different programs; a matrix generator program, an L-P solver and a report writer. (6)

The linear program solver is the basic component of the model, in that it finds the solution. The model's purpose is to find the profit maximizing combination of crops given a certain set of resources and tillage practices. With the matrix generator, the user can change the set of resources and tillage practices to find the effect on income. The user can also place limits or bounds on the acreage of each crop, e.g., if the user wants to grow no more than 100 acres of wheat, that

can be specified using the matrix generator. (6)

The program itself does not choose the size of equipment that would be optimum for that size of operation. Size of equipment is specified by the user. Also, the time available for each operation is a function of the available workdays during the period in which the operation is performed. The available workdays are influenced by weather, soil types and type of crop. As of this writing the Purdue model left the estimation of the time available for field work up to the user, however they are currently working on a model to estimate available workdays from meteorological data for Indiana.

The matrix generator is a program used to change or develop the values used in the linear program matrix. (6) Use of this generator allows the user to reflect such information as workdays available, size of equipment, tillage practices and size of farm.

The report writer program analyzes the linear programming solution and writes up the results in such a way that the farmer, by himself, or with the help of his extension representative, will be able to interpret the results. (6)

CHAPTER III

DEVELOPMENT OF THE MODEL

"Linear programming is a mathematical technique designed to analyze the potentialities of alternate business activities and to choose those that permit the best use of resources in the pursuit of a desirable objective". (17) The technique of linear programming can be applied to a problem whenever the objective is to maximize or minimize the function $f(x)$ where $f(x) = FX + K$. (1) The function $f(x)$ is linear and F is a functional, K is a constant and X ranges over a convex polyhedral set of points. (1) The maximization of the objective function is subject to certain linear constraints and can be written in matrix form as follows: (1)

Maximize $Z = C'X$ subject to

$AX = B, X \geq 0$ where

A is an $m \times n$ matrix of technical coefficients

C is an $n \times 1$ vector of prices or other weights for the
objective function

X is an $n \times 1$ vector of activities

B is an $m \times 1$ vector of resources or other restraints, and

$C'X = Z$ is the objective function. (1)

In algebraic form this can be written as:

Maximize $Z = c_1x_1 + c_2x_2 + \dots + c_nx_n$ subject to

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n = b_1$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n = b_2$$

$$\vdots$$

$$\vdots$$

$$\vdots$$

$$\vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n = b_m$$

(1)

There are several assumptions and limitations of linear programming that one should be aware of when utilizing this tool.

Programming cannot predict prices. Prices of inputs and outputs must be given by the programmer or developed through some other programming procedure.

Programming assumes that there is no 'risk' involved in the activities in the program. Thus operator preferences will not be considered by the program unless those 'risky' activities are left out of the program entirely or artificial bounds are placed on those activities by the programmer. This assumption is often referred to as single-valued expectations. (5)

Programming cannot estimate or predict input-output relationships between resources and products. These relationships must be estimated by the programmer based on management ability and quality of inputs used by the producer.

Linear programming, as the name implies, assumes a linear relationship between inputs and outputs for each specified activity. This assumption violates the characteristic of diminishing returns which most production activities possess. However, when it is important to show diminishing returns, additional activities are needed, each one specifying different combinations of resources used and each one limited to a specific number of units.

Complete divisibility of activities and resources is an assumption which implies that all resources can be broken down and used in minute quantities. For many inputs or resources this is not a critical assumption. However, for tractors, combines and all other machinery,

usually whole units must be introduced into the program to make sense of the results.

As previously stated, linear programming is a mathematical solution to a business problem. This 'mathematical solution' is a maximizing procedure subject to a simultaneous equation problem, where each resource use (or productivity) is given by a linear equation with each activity as a variable in that equation. The 'desirable objective' of the model developed here is the maximization of farm income. The main activities the model uses to maximize farm income are 'wheat', 'corn', 'grain sorghum' and 'soybeans' activities. Other activities include hiring part-time labor, buying additional equipment and hiring full-time labor.

Each crop activity is linked to activities specifying plowing, preparing, planting, cultivating and harvesting. Each crop activity defines the profitability of growing one acre of that crop based on the yield, price and variable costs.

The tillage activities linked to a crop activity require the labor, machinery and field workdays necessary to produce that crop. For this study the per acre variable costs of fuel, oil and machinery repairs are considered the same for both three and four plow equipment. With three plow equipment it takes more time to complete one acre unit of a crop activity but the rate of fuel consumption per hour is less than four plow equipment. For larger differences between equipment sizes, economies of size are significant, therefore the fuel, oil and repair expenses per acre are less than small equipment sizes. The difference between three and four plow equipment is not large, thus economy of

size associated with larger equipment is not a significant factor.

The tillage activities specify the labor, machinery capacity and field workdays, in hours, necessary to produce a crop activity. The objective value of the crop activities includes expenses of all the tillage operations for that crop, the only cost included in the objective value for tillage activities is the cost due to untimely performance of that activity. However, if per acre costs of fuel, oil and repairs differ by size of equipment, this model is capable of considering these differences.

Each resource used by an enterprise has an equation associated with it. On the right hand side (RHS) of the equation is the amount of resource (b_i) available. On the left hand side of the equation are variables (X_i) representing activities which use the resource of amount specified by a coefficient (a_i).

The type of equation is defined as less than (L), greater (G), or equal to (E). (16)

If a row is specified as 'L', the activities may use any amount of the resource, up to and including, but not more than specified in the RHS. If a row is specified as 'G', the amount of resource used by the activities must be any amount equal to, or greater than, that specified in the RHS. This type of equation is often encountered in a least cost ration problem. For the purpose of this model, the 'G' option is not utilized. If a row is specified as 'E', the value used by the activities must be equal to the amount of resource available in the RHS.

The program finds the maximum value of the objective function subject to the resource constraints expressed by the type of each equation. Each variable in the equation (row) is associated with a given activity (column). The combination of all the rows and columns of the linear programming problem will hereafter be referred to as the matrix.

Resources Available RHS

The RHS (right hand side) column of the matrix gives the resources available and in an economic sense are the fixed inputs of the operation. In this study equipment, land and labor are the resources considered fixed and available at no additional cost.

The object row of the matrix has no RHS value since this is the row which is being maximized.

The land available is total crop acres and is an 'L' type row so that non-use of land is possible.

Eighteen rows in the model are the labor available during the growing season, subdivided into two week periods. The growing season is divided into small enough time periods to restrict time available for field work during critical planting and harvesting operations. The amount of labor available during each of these periods is calculated by multiplying the number of field workdays by the hours worked per field workday. (11) These rows are 'L' type rows to allow for non-use of labor.

Another set of rows in the model link crop growing activities with tillage activities and have no value in the RHS of the matrix. These rows specify that necessary tillage operations are done and at the proper

time: for each rows are 'E' type rows.

The last set of rows in the model is limits on machinery capacity. The capacity of a machine is calculated by the field workdays available times the number of hours per day during the periods in which the machine is used.

Development of Activities

Many activities can be developed for a model of this nature and the manner in which they are developed can also vary significantly. This model has one activity for each crop which contains the optimum income value in its object row. Each crop activity is linked to appropriated tillage and harvesting activities at appropriate times of the year. The tillage activities for each crop specifies the field work days and machines required to perform that activity and also includes a penalty if the activity concerned is performed at a time which would result in less than the optimum yield.

Other activities included are the purchase of part-time and full-time labor, buying various pieces of machinery and trading one size of equipment for another.

THE MODEL FOR NORTHEAST KANSAS

The model considers machinery selection and production decisions for a typical northeast Kansas cash-grain farmer. The four crops the model considers are wheat, corn, grain sorghum and soybeans.

The model can be adapted to study the effect of changes in prices, tillage practices, size of farm and labor availability. Since most farms in northeast Kansas are family farms, this model assumes a one man operation with the option to hire part-time labor during the spring, summer and portions of the fall periods.

Resources Available (RHS)

Kasper adopted the 'Versatile Soil Moisture System' by Baier, Chaput, Russello and Sharp, using meteorological data from various sites in Kansas to estimate the days available for field work in northeast and other sections of Kansas. (15) The growing season was broken down into two week or half month periods beginning April 1, and ending October 31. Since data from "Field Worksays in Kansas" is available only through October 31 estimates of the field workdays available for November and December were made. All the necessary weather data was not available to use the Versatile Soil Moisture System to estimate field workdays for November and December. November and December each average less rainfall than October, however, they are also cooler. The soil surface takes longer to dry under cooler temperatures. Field workdays are then estimated to have as few or fewer workdays than October.

Two sets of values for the number of field workdays are estimated. One set of values estimates the average number of field workdays expected per period. This average is based on weighing the number of field workdays by the probability of that number of workdays occurring. (7) The other set of values estimates a minimum number of field workdays expected

per period. This minimum is based on 85% of the years having more than the minimum number of field workdays. (7) (See Table 3.1). To study the effects of limited number of field workdays on crop acreage and machinery size selection, both sets of values are used.

The following 43 rows have no values in the RHS section of the matrix because they are used to link crop activities with tillage and harvesting activities. These transfer rows serve two purposes, first, to provide that all necessary operations are performed to produce an acre of a given crop. If one acre of corn is to be produced, then a preparing corn activity, a planting corn activity, a cultivating corn activity and a harvesting corn activity must all enter basis to acquire the income from producing an acre of corn. A choice of most profitable sized equipment is made simultaneously with the choice of crop. The second purpose is to provide or allow for a choice among various sized equipment. Often both preparation and planting occur during the same period. These rows provide that preparation must be completed prior to planting, planting before cultivation, etc. They also provide proper time spacing between planting and cultivating activities and between planting and harvesting activities. These transfer rows are 'E' rows, thus, the requirement that equal acres of preparing, planting, etc. of the related crop, be performed.

Four 'E' rows are used to supply an integral number of resources to operation. These rows are used to specify whether 0, 1, 2, n, integral number of tractors or another resource is to be bought by the program.

TABLE 3.1

FIELD WORKDAYS FOR NORTHEAST KANSAS

PERIOD	AVERAGE FIELD WORKDAYS	HOURS ^{/1} (RHS)	MINIMUM FIELD WORKDAYS	HOURS (RHS)
April 1-15	9	108	3	36
April 16-30	9	108	4	48
May 1-15	8	96	4	48
May 16-31	6	72	2	24
June 1-15	7	84	1	12
June 16-30	8	96	2	24
July 1-15	9	108	4	48
July 16-31	11	132	5	60
August 1-15	11	132	7	84
August 16-31	10	120	5	60
September 1-15	8	96	1	12
September 16-30	7	84	0	0
October 1-15	8	96	1	12
October 16-31	9	108	2	24
*November 1-15	8	96	2	24
*November 16-30	7	84	1	12
*December 1-15	6	72	1	12
*December 16-31	5	60	2	24

* Estimates

^{/1}The hours available during each period are based on a twelve hour workday.

The remaining rows in the matrix are associated with the capacity of equipment. Machinery resource rows are 'L' rows, to allow for use at less than full capacity. The value for each machine in the RHS of the matrix is based on the period of the year the machine is used and the field workdays available during that period. The values in the RHS column of the matrix are the product of the number of field workdays in the period the machine is used times the number of hours per workday. (12) Some machines are used in both spring and fall planted crops. To separate the times associated with each use, two rows with the capacity for each season are used. Table 3.2 lists the machinery capacity for three and four-plow equipment for minimum and average field workdays in northeast Kansas.

Development of Objective Row Values

For wheat, an object value of \$104.65 is used. The price, yield and expense figures reflect the most recent figures published by the cooperative extension service for northeast Kansas. (10) The same procedure is used to calculate the object values of \$143.50 for corn, (9) \$120.60 for grain sorghum, (11) and \$125.45 for soybeans. (8) Table 3.3 lists the income and expense items included in the above object values.

The operator labor expense, depreciation and other machinery ownership costs were excluded from the calculation of the objective values. The reason for excluding operator labor is based on the fact that hiring labor is a separate activity and operator labor is considered a fixed cost. It would therefore be counted twice if it were included under the crop activity. If activity specifies using owned equipment,

TABLE 3.2

MACHINERY CAPACITIES*

MACHINE	MINIMUM FIELD WORKDAYS	AVERAGE FIELD WORKDAYS
Plow	192 (hrs.)	372
Annhydrous applicator (spring)	192	372
Annhydrous applicator (fall)	156	432
Disc (spring)	192	564
Disc (fall)	156	432
Spring tooth (spring)	192	564
Spring tooth (fall)	156	432
Field cultivator	168	564
Planter	204	456
Drill	48	384
Rotary hoe	216	552
Cultivator	228	552
Combine (spring)	132	336
Combine (fall)	108	600

*The capacity for both three and four-plow equipment is the same since the the capacity is based on time.

TABLE 3.3
TABLE OF OBJECTIVE VALUES

CROP	WHEAT	CORN	GRAIN SORGHUM	SOYBEANS
YIELD (Bu./Acre)	40	85	80	35
PRICE (\$/Bu.)	<u>3.75</u>	<u>2.50</u>	<u>2.25</u>	<u>5.00</u>
REVENUE (\$/Acre)	150	212.50	180	175
VARIABLE COSTS				
Seed	6.40	6.25	1.20	10.00
Herbicide, Ins.	1.00	8.50	6.50	12.50
Fert. & Lime	21.45	29.00	26.70	11.30
Fuel & Oil	5.50	6.25	6.00	5.25
Repairs	9.50	9.00	9.50	9.00
Drying		8.50	8.00	
Misc.	<u>1.50</u>	<u>1.50</u>	<u>1.50</u>	<u>1.50</u>
OBJECTIVE VALUES	104.65	143.50	120.60	125.45

depreciation is a fixed cost and is not included in the object value. However, when purchasing equipment activities are considered, the depreciation of that equipment is not a fixed cost and is included in the object value.

The object value for hiring part-time labor is \$4.00 per hour which is the cost of labor and an estimate of the value of supervising the laborer.

When full-time labor is hired the objective value is the rate of pay times the number of field work hours in a year. A rate of \$3.00 per hour is used for this model. (10)

The object values for buying tractor and combine activities includes depreciation. (23) For tractors a seven year life and 15% salvage value is assumed and for combines a ten year life and 10% salvage value is

assumed. Table 3.4 contains a complete list of recent machinery costs and their depreciation values.

Timeliness of Field Operations

This model considers the timing of field operations. Penalty data, however, are scarce and this model includes only penalties for untimely planting. Timeliness of harvesting is also important, but reliable data for crops is not available.

A study completed in 1964 lists the yield of different dates of planting wheat for various areas of Kansas. (13) Manhattan data is used for this model. Since the optimum yield is higher now than in the study consulted, proportionate yields for the different time periods is assumed. The data for the Manhattan station covers a nine year period. The optimum dates for planting wheat for northeast Kansas are September 16-30 with a yield of 40 bushels per acre. (13) (10)

The optimum date for planting corn is derived from a series of studies from 1959-61 and 1963-72. (2) The procedure used is to find the years each period produced the highest yield, then average those yields to arrive at an average yield for that period. These yields are then made proportionate to reflect a yield of 85 bushels per acre for the period of May 16-31, since this period has the highest average. (9) (2)

The optimum date for planting grain sorghum is from a study conducted between 1958 and 1962. (22) The yields are averaged over these years for the different periods of planting. The optimum periods to plant grain sorghum for northeast Kansas is between May 1-31. Since the yield for optimum planting used for this model is the same as that

TABLE 3.4

MACHINERY PRICES AND DEPRECIATION

MACHINE	PRICE ^{/1}		ANNUAL DEPRECIATION ^{/2}	
	Three Plow	Four Plow	Three Plow	Four Plow
Plow	\$1420	2370	142	237
Annhydrous applicator	1700	2000	170	200
Disc	2750	4030	275	403
Spring tooth	826	826	82.60	82.60
Field cultivator	1850	1850	185	185
Planter	4180	6960	418	969
Drill	2590	3440	259	344
Rotary hoe	1270	1758	127	175.80
Cultivator	1150	1600	115	160
Combine	21600	28300	1944	2547
Corn header	6290	9320	566.10	838.80
Tractor	<u>8100</u>	<u>12000</u>	<u>984</u>	<u>1457</u>
TOTALS	53726	72454	5267.70	7326.20

Difference in annual depreciation: \$2058.50

^{/1}USDA Statistical Reporting Service, Crop Reporting Board, 'Agricultural Prices'. Washington, D.C. April 30, 1976, Annual Summary 1974, January 30, 1976.

^{/2}Depreciation values are calculated using 10 per cent salvage value for combines with a ten year life; for tractors, a 15 per cent salvage value and a seven year life; and for all other machinery a ten year life with no salvage value.

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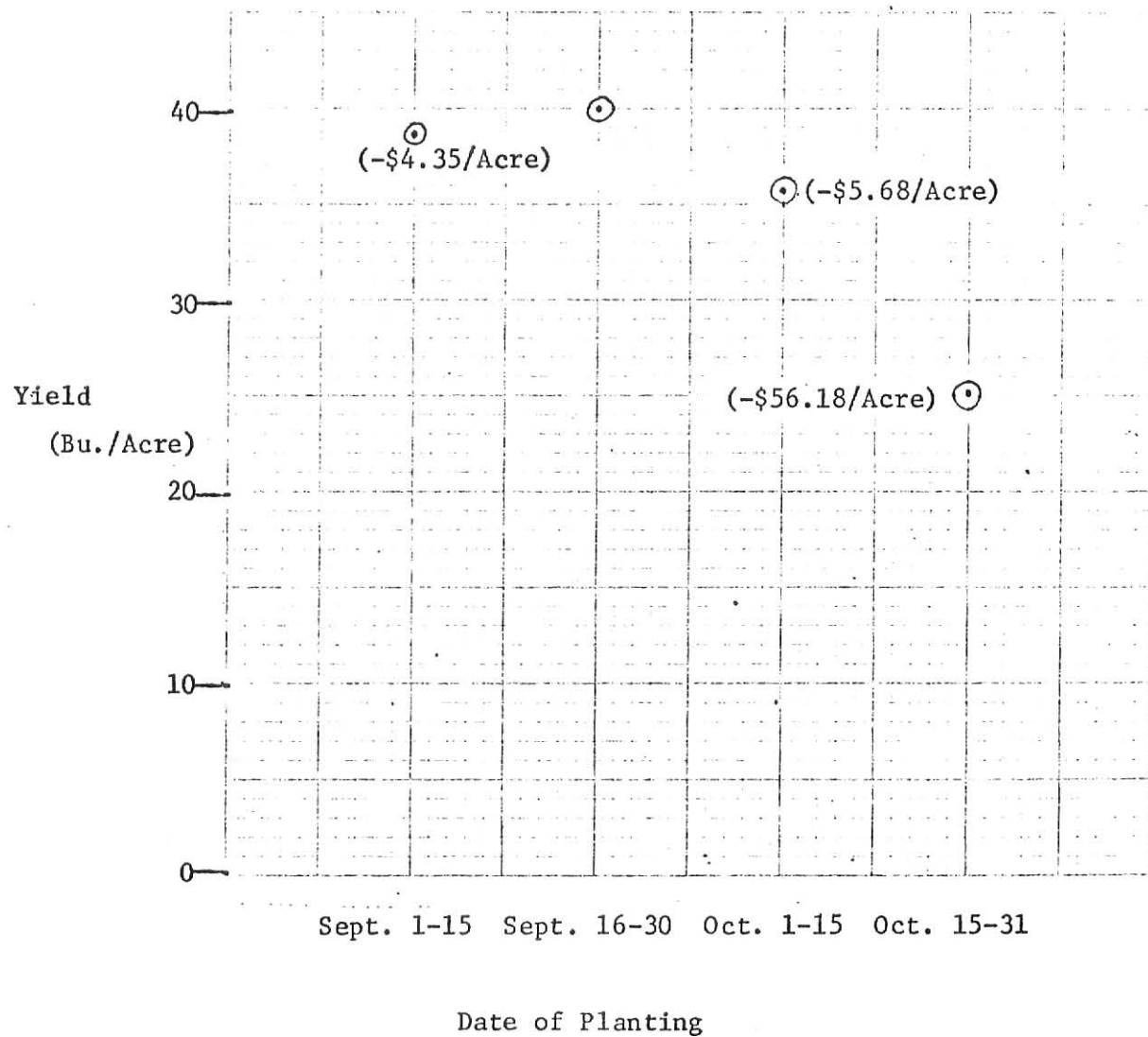
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GRAPH 3.1

YIELD VS. DATE OF PLANTING

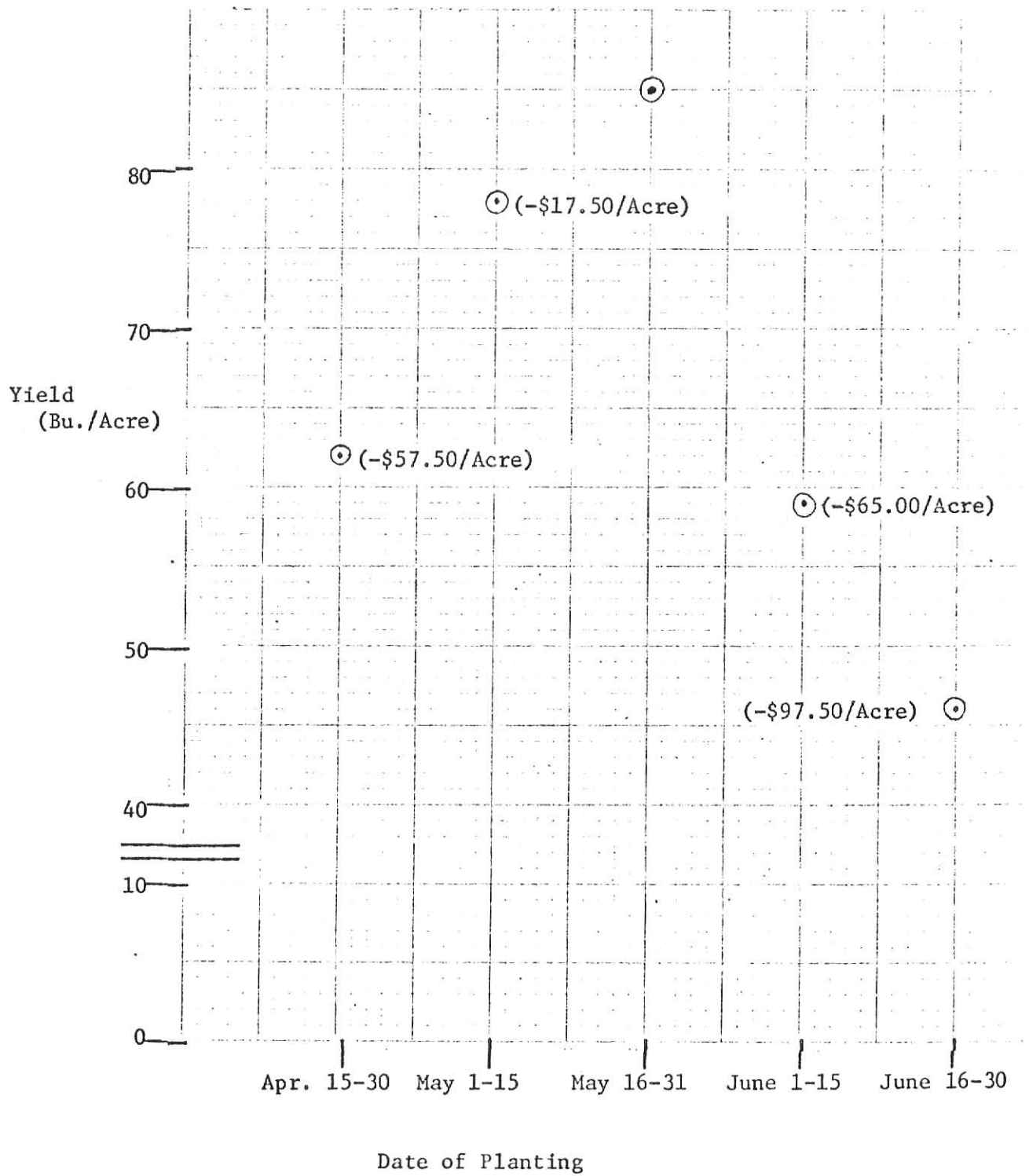
WHEAT



GRAPH 3.2

YIELD VS. DATE OF PLANTING

CORN



in the study consulted, the yields for the non-optimum periods for this model are the same as those non-optimum yields in the above study.

The optimum planting dates for soybeans are from a study by Robert F. Sloan in 1972 and 1973. (3) In this study, yields are not significantly different between May 1 and June 15. There is no penalty for planting in these periods and the penalties for the other periods are calculated in the same manner as used previously. Graphs 1 through 4 show the relationship between yield and date of planting for northeast Kansas.

Determining Field Capacity of Machinery

Field capacity of machinery refers to the acreage which can be covered by the machine in a given amount of time. Crop, tillage and harvesting activities are based on one acre per unit, thus machinery capacity is in hours per acre.

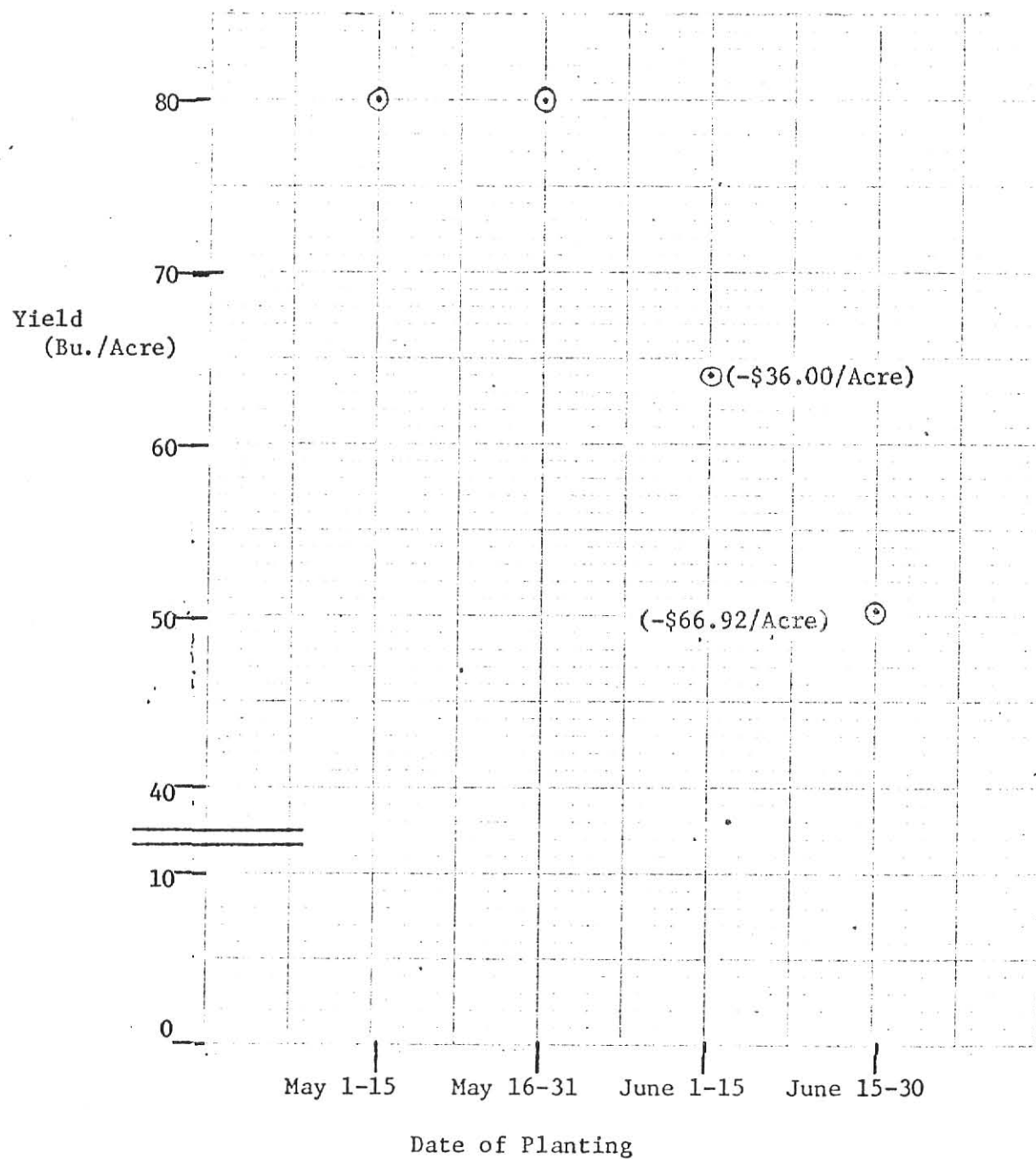
Field capacity of a machine is determined by three factors: (1) the speed of the machine; (2) the effective width of the machine; and (3) the efficiency of the operation. (12) The speed of the machine is 10-20 percent lower than that indicated by the tractor speedometer, due to slippage. (12) The effective width of the machine is affected by overlapping or the failure to use 100 percent of the machine's width or capacity, and under-lapping (not very common for most machines except for balers, forage cutters, etc.) where the width of the field 'covered' by the machine is greater than the actual width of the machine. The width of the machine is measured in feet.

The efficiency factor considers such factors as servicing, repairs, adjustments, etc., since these influence the time which can be spent

GRAPH 3.3

YIELD VS. DATE OF PLANTING

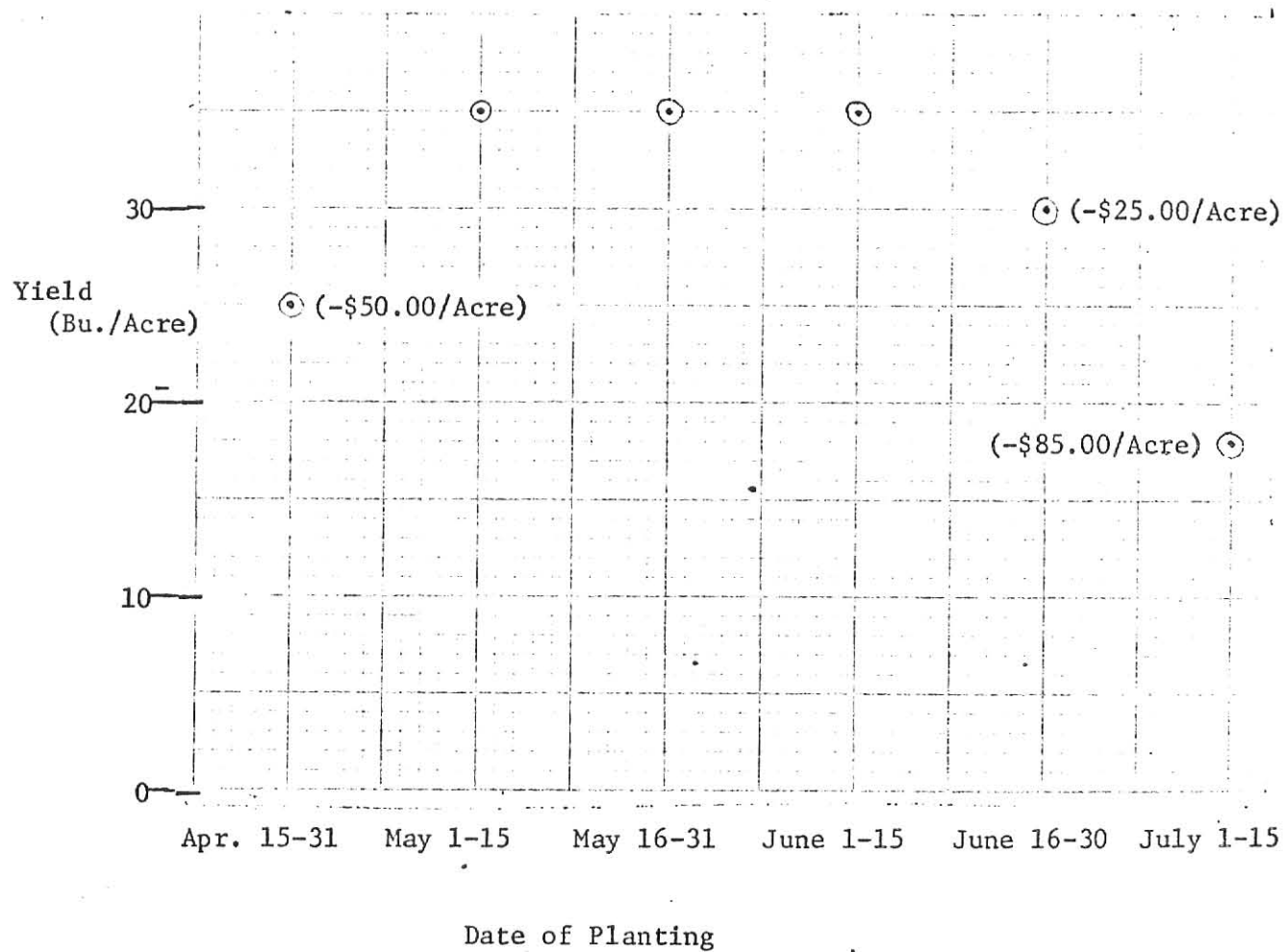
GRAIN SORGHUM



GRAPH 3.4

YIELD VS. DATE OF PLANTING

SOYBEANS



performing a given field operation.

The equation used to calculate field capacity in acres per hour is:

$$\text{Field Capacity} = \frac{\text{Speed (mph)} \times \text{Effective Width (ft)} \times \text{Efficiency}}{8.25} \quad (12)$$

An example of this calculation is illustrated below. Suppose the field capacity of a disc is desired. The effective width of the disc is 12 feet, pulled at a rate of 4 mph with 80 percent efficiency, the field capacity would then be:

$$\frac{(4) (12) (0.80)}{8.25} = 4.65 \text{ acres/hour.}$$

For this model, hours/acre is required, therefore, we need the inverse of 4.65 or $1/4.65 = 0.21$ hours/acre.

A complete list of field capacity coefficients in hours/acre for other machines can be found in Table 3.5.

Determination of Machinery Coefficients for the Matrix

The machinery coefficients estimate the time for a machine to complete one acre of the specified activity. To estimate the hours/acre for preparing, planting or cultivating, the field capacity of a machine is multiplied by the number of times it is used. The machinery coefficients are in Table 3.5.

Several field operations may be required for each activity, therefore, the tractor coefficients are the sum of the machinery coefficients for each operation.

TABLE 3.5(a)

MACHINERY COEFFICIENTS AND LABOR COEFFICIENTS BY ACTIVITY - 3-PLOW

	TIMES OVER	EFEC- TIVE WIDTH (feet)	SPEED (mph)	EFFICIENCY (ratio)	MACHINERY COEFFICIENT (hrs/acre)	LABOR COEFFICIENT (hrs/acre)
A. WHEAT						
PLOW		4	4	0.80	0.64	0.64
PREPARE						
disc	2	12	4	0.80	0.42	
spring tooth	1	16	4	0.80	0.16	
annhydrous	1	12	4	0.60	<u>0.29</u>	
Total						
Preparation					0.87	0.87
PLANT						
drill	1	10	4.5	0.65	0.28	0.28
HARVEST						
combine	1	12	2	0.65	0.53	<u>0.53</u>
						2.32
B. CORN						
PREPARE						
annhydrous	1	12	4	0.60	0.29	
disc	2	12	4	0.80	0.42	
field						
cultivate	1.5	14	4	0.80	<u>0.27</u>	
Total						
Preparation					0.98	0.98
PLANT						
planter	1.2	12	4	0.50	0.41	0.41
CULTIVATE						
rotary hoe	1	14	7	0.75	0.11	
cultivator	1	12	2	0.80	0.43	
cultivator	1	12	4	0.80	<u>0.21</u>	
Total						
Cultivation					0.75	0.75
HARVEST						
combine	1	12	2	0.50	0.69	<u>0.69</u>
						2.83

TABLE 3.5(a) (continued)

	TIMES OVER	EFFEC- TIVE WIDTH (feet)	SPEED (mph)	EFFICIENCY (ratio)	MACHINERY COEFFICIENT (hrs/acre)	LABOR COEFFICIENT (hrs/acre)
C. GRAIN SORGHUM						
PREPARE						
annhydrous	1	12	4	0.60	0.29	
disc	1	12	3.5	0.80	0.21	
disc	1	12	4	0.80	0.19	
spring tooth	1	16	4	0.80	<u>0.13</u>	
Total						
Preparation					0.82	0.82
PLANT						
planter	1.2	12	4	0.55	0.38	0.38
CULTIVATE						
cultivator	1	12	3	0.80	0.34	
cultivator	1	12	5	0.80	<u>0.21</u>	
Total						
Cultivation					0.55	0.55
HARVEST						
combine	1	12	2.5	0.50	0.55	<u>0.55</u>
						2.30
D. SOYBEANS						
PREPARE						
annhydrous	1	12	4	0.60	0.29	
disc	2	12	4	0.80	0.42	
field						
cultivate	1	14	4	0.80	<u>0.18</u>	
Total						
Preparation					0.89	0.89
PLANT						
planter	1.1	12	4	0.50	0.37	
CULTIVATE						
cultivator	1	12	2.5	0.80	0.34	
cultivator	1	12	4	0.80	<u>0.21</u>	
Total						
Cultivation					0.55	0.55
HARVEST						
combine	1	12	2.5	0.50	0.59	<u>0.59</u>
						2.40

TABLE 3.5(b)

MACHINERY COEFFICIENTS AND LABOR COEFFICIENTS BY ACTIVITY - 4-PLOW

	TIMES OVER	EFEC- TIVE WIDTH (feet)	SPEED (mph)	EFFICIENCY (ratio)	MACHINERY COEFFICIENT (hrs/acre)	LABOR COEFFICIENT (hrs/acre)
A. WHEAT						
FLOW		5.33	4	0.80	0.48	0.48
PREPARE						
annhydrous	1	14	4	0.60	0.25	
disc	2	14	4	0.80	0.37	
spring tooth	1	16	6	0.80	<u>0.11</u>	
Total						
Preparation					0.73	0.73
PLANT						
drill	1	12	4.5	0.65	0.24	0.24
HARVEST						
combine	1	14	2	0.65	0.45	<u>0.45</u>
						1.90
B. CORN						
PREPARE						
annhydrous	1	14	4	0.60	0.25	
disc	2	14	4	0.80	0.37	
field						
cultivate	1.5	14	6	0.80	<u>0.18</u>	
Total						
Preparation					0.80	0.80
PLANT						
planter	1.2	15	4	0.50	0.33	0.33
CULTIVATE						
rotary hoe	1	18	7	0.75	0.09	
cultivator	1	15	2	0.80	0.34	
cultivator	1	15	4	0.80	<u>0.17</u>	
Total						
Cultivation					0.60	0.60
HARVEST						
combine	1	14	2	0.50	0.59	<u>0.59</u>
						2.32

Table 3.5(b) (continued)

	TIMES OVER	EFFEC- TIVE WIDTH (feet)	SPEED (mph)	EFFICIENCY (ratio)	MACHINERY COEFFICIENT (hrs/acre)	LABOR COEFFICIENT (hrs/acre)
C. GRAIN SORGHUM						
PREPARE						
annhydrous	1	14	4	0.60	0.25	
disc	1	14	4	0.80	0.18	
disc	1	14	4.5	0.80	0.16	
spring tooth	1	16	6	0.80	<u>0.11</u>	
Total Preparation					0.70	0.70
PLANT						
planter	1.2	15	4	0.55	0.30	0.30
CULTIVATE						
cultivator	1	15	3	0.80	0.23	
cultivator	1	15	3	0.80	<u>0.14</u>	
Total Cultivation					0.37	0.37
HARVEST						
combine	1	14	2.55	0.50	0.46	<u>0.46</u>
						1.83
D. SOYBEANS						
PREPARE						
annhydrous	1	14	4	0.60	0.25	
disc	2	14	4	0.80	0.37	
field cultivate	1	14	6	0.80	<u>0.12</u>	
Total Preparation					0.74	0.74
PLANT						
planter	1.1	15	4	0.50	0.30	0.30
CULTIVATE						
cultivator	1	15	2.5	0.80	0.28	
cultivator	1	15	4	0.80	<u>0.17</u>	
Total Cultivation					0.45	0.45
HARVEST						
combine	1	14	2.25	0.50	0.52	<u>0.52</u>
						2.01

Determination of Labor Coefficients

The labor coefficient is the amount of labor in hours per acre required to complete one unit (acre) of the activity. The labor coefficients are determined from the machinery coefficients. Since the efficiency factor for the machines takes into consideration time spent repairing, adjusting, servicing, etc., the sum of the machinery coefficients for a given activity is used as an estimate of the labor required to complete an acre of a given activity.

The total labor requirements for each of the four crops are nearly the same as those estimated for the crops in eastern Kansas. (16) Differences are due to time spent between November 1, and March 31; this period is not covered by this model. The reasons for not including this time period in this model are: (1) meteorological data necessary to calculate field workdays during this period are not available; and (2) field work during this period is considered not critical, meaning that timeliness has little effect on yield.

Included in the appendix is a copy of the matrix. The values in the RHS are those for average field workdays. This matrix includes all the activities which are developed for the model. Not all of these activities remain in the matrix for each use, however, but are included to illustrate all the activities which were developed for this model.

CHAPTER IV

RESULTS OF THE MODEL FOR NORTHEAST KANSAS

To test the model for northeast Kansas, four combinations of machinery size and field workdays, with a fixed amount of labor, and land are analyzed. The four combinations are as follows:

- Run 1. Minimum field workdays, one man labor unit, three plow equipment, 522 acres.
- Run 2. Minimum field workdays, one man labor unit, four plow equipment, 522 acres.
- Run 3. Average field workdays, one man labor unit, three plow equipment, 522 acres.
- Run 4. Average field workdays, one man labor unit, four plow equipment, 522 acres.

The results from these four runs are as follows:

TABLE 4.1

RESULTS OF LAND USE AND CROP ACREAGE FOR AVERAGE AND MINIMUM NUMBER OF FIELD WORKDAYS WITH THREE AND FOUR PLOW EQUIPMENT CAPACITY

RUN	FIELD WORK- DAYS	FARM SIZE	USED	OBJECT VALUE	WHEAT ACRES	CORN ACRES	GR. SOR. ACRES	SOY- BEAN ACRES	LABOR UNITS	EQUIP SIZE
1	Min.	522	231.13	17681.40	83.83	58.54	20.00	68.76	1	3
2	Min.	522	284.49	21508.26	114.87	72.73	14.37	82.52	1	4
3	Ave.	522	522.00	47035.87	168.69	175.61		117.70	1	3
4	Ave.	522	522.00	50196.99	90.88	218.18		212.94	1	4

The results verify that the model makes plausible selections of tillage dates, crop selection and machinery size within the limits of land and field work days available.

Average Size Farm - Northeast Kansas, 1974

To test the model, the results from the four combinations are compared with the average acreage of crops for northeast Kansas as reported in the 1974 Farm Management Summary and Analysis Report for Association No. 4. Those average acreages are as follows:

Wheat	87 acres
Corn	204 acres
Grain Sorghum	122 acres
Soybeans	109 acres

These acreages are based only on the number of farms that grow each crop and not on the total number of farms in Association No. 4.

From the Summary and Analysis Report 1974 for Association No. 4, the average total acres operated per farm is 930 with 54.82 percent tillable or 510 acres tillable per farm. All farms in northeast Kansas do not grow all four crops, since the total of the average acres of each crop totals 522 acres. Of 260 cash grain farms in northeast Kansas, 243 farms have wheat, 188 farms have corn, 190 farms have grain sorghum and 208 farms have soybeans. Farmers tend to specialize in two of the spring crops and if the third spring crop is used, it is included in small acreages.

Combination of Crops Grown by Farm in Northeast Kansas

The mix of spring crops by farm is difficult to determine from data in the Farm Analysis and Summary Report Association No. 4. The average acres of a crop is based on the farms which grow that crop. The sum of these acreages is not characteristic of an average northeast Kansas farm. The data shows that only two of the spring crops are grown by northeast Kansas farmers; either corn and soybeans, corn and grain sorghum or grain sorghum and soybeans. The crop mix of 99 farms reported by farmers in Farm Management Association No. 4 in 1974 is listed in the table below:

TABLE 4.2
CROPS GROWN BY FARM

CROP COMBINATION	NO. OF FARMS
Wheat, Grain Sorghum, Corn, Soybeans	29
Wheat, Grain Sorghum, Soybeans	20
Wheat, Corn, Soybeans	15
Wheat, Grain Sorghum	13
Wheat, Grain Sorghum, Corn	8
Wheat, Corn	3
Corn, Soybeans	3
All Other Combinations (less than 3 crops/farm)	8

Most farms in northeast Kansas do not grow all four major cash grain crops. Most farms grow wheat and one or two of the spring crops.

Determining Field Workdays in 1974

Using the Soil Moisture Budget System, field workdays for 1974 were estimated using meteorological data from Sabetha Lake. This data was used to calculate the average field workdays based on 26 years (1949-1974) of data. The table below gives the estimates of field workdays for 1974 and the average field workdays for northeast Kansas used in this model.

TABLE 4.3
ESTIMATED FIELD WORKDAYS FOR 1974

MONTH	ESTIMATED ^{/1} FIELD WORKDAYS FOR 1974	AVERAGE ^{/2} FIELD WORKDAYS	<u>FIRST HALF OF MONTH</u>		<u>SECOND HALF OF MONTH</u>	
			ESTIMATED FOR 1974	AVERAGE	ESTIMATED FOR 1974	AVERAGE
April	22	18	13	9	99	9
May	15	14	8	8	7	6
June	17	15	2	7	15	8
July	31	20	15	9	16	11
August	16	21	7	11	9	10
September	9	15	5	8	4	7
October	<u>13</u>	<u>17</u>	<u>9</u>	<u>8</u>	<u>4</u>	<u>9</u>
TOTALS	123	120	59	60	64	60

^{/1} These estimates are based on the Soil Moisture Budget System with 1974 data from the Sabetha weather site.

^{/2} The average field workdays are based on 26 years of meteorological data from the Sabetha Lake.

The average number of workdays and workdays estimated for 1974 are nearly the same from April 1 to October 31. Dividing the year into three periods (April 1 - June 15; June 16 - August 31 and September 1 - October 31), the field workdays available for preparing and planting of spring crops (April 1 - June 15) in 1974 are nearly the same as the field workdays available in an average year. For the summer period, 1974 has thirteen more field workdays available than the average year. The fall for 1974 has ten fewer field workdays than the average year. Since more days are available in the summer of 1974 than the average year, the additional time can be used to prepare wheat ground. Results using the average field workdays are compared with the acreages and equipment sizes used by farmers in northeast Kansas in 1974.

Model Results - Average Field Workdays, Four Plow Equipment

Using 522 acres, average field workdays and four plow equipment, the model chooses the following crop combination: corn, 218.18 acres; soybeans, 212.94 acres; and wheat, 90.88 acres.

The limiting resources for this combination are land and spring labor. The periods in which all the available labor is used are Ap. 1, Ap. 2, Ma. 1, Ma. 2, Jn. 1, and Jn. 2. All the other periods have unused labor resources.

The shadow price for land is \$63.15. This indicates that an additional acre of land will increase the objective function \$63.15. In this case if an additional acre is available, it will be planted to wheat since there is slack labor and machinery capacity available in each period associated with the wheat activities. Therefore the acreages of corn and soybeans are unaffected.

The shadow prices for labor are as follows: Ap. 1, 30.67; Ap. 2, 30.67; Ma. 1, 30.67; Ma. 2, 70.64; and Jn. 1, 30.67. If the amount of labor is increased by one hour in any of the periods above, the objective value will be increased by the shadow price for that period. The shadow price during Ma. 2 is higher because both corn and soybeans may be planted during this period. An increase in one hour of planting time is more valuable than one hour of preparing time.

The shadow prices for the crop resource rows are: corn, 47.85; grain sorghum, 15.95; soybeans, 39.13; wheat, 0. These shadow prices show the relative importance of each crop with respect to the objective function. A zero shadow price for wheat does not mean that an additional acre of wheat is worth nothing to the farmer.

Model Results - Average Field Workdays, Three Plow Equipment

Using 522 acres, average field workdays and three plow equipment, the model chooses the following crop combination: corn, 175.61 acres; soybeans, 177.70 acres; and wheat, 168.69 acres.

The limiting resources for this combination are land, and spring labor. The periods in which all the available labor is used are Ap. 1, Ap. 2, Ma. 1, Ma. 2 and Jn. 1. All remaining periods have slack labor.

The shadow price for land is 63.15.

The shadow prices for labor are as follows: Ap. 1, 25.32; Ap. 2, 25.32; Ma. 1, 25.32, and Jn. 1, 56.19. The interpretation of the shadow prices are the same as before.

The shadow prices for the crop resource rows are: corn, 47.85; grain sorghum, 15.95; soybeans, 31.90; and wheat, 0.

Comparing this combination with the four-plow combination, the crop shadow prices are the same in each while the shadow prices for labor are different. The shadow prices for labor in the four-plow combination reflect the greater productivity of four plow equipment versus three plow equipment. It should not be interpreted to mean that the labor in the four plow combination is more efficient. Because the objective values for the crop activities for three and four plow equipment are the same, the shadow prices for the crop resource rows are the same.

Model Results - Minimum Field Workdays, Four Plow Equipment

Using 522 acres, minimum field workdays and four-plow equipment, the model chooses the following crop combination: corn, 72.73 acres; grain sorghum, 14.37 acres; soybeans, 72.52 acres; and wheat, 114.87 acres.

The limiting resource for this combination is labor. All available labor in every period is used.

Because land is not fully utilized (237.51 acres) it has a zero shadow price.

The shadow prices for labor are: Ap. 1 - Ma. 1, 78.95; Ma. 2, 100.28; Jn. 1, 78.95; Jn. 2 - Jl. 2, 0.75; Au. 1, 0.63; Au. 2, 0.75; Sp. 2, 258.31; Oc. 1, 159.71; and Oc. 2 - Dc. 2, 24.23. The high shadow prices for spring labor again reflect the value of preparing and planting of spring crops. The very high shadow price for Sp. 2 results from no labor resource available during that period. It also is the time when both harvesting of spring crops begin and when planting of wheat results in the highest yield.

The shadow prices for the crop resource rows are: wheat, 63.15; corn, 111.00; grain sorghum, 79.10 and soybeans, 95.05.

Model Results - Minimum Field Workdays, Three Plow Equipment

Using 522 acres, minimum field workdays and three plow equipment, the model chooses the following crop combination: wheat, 83.83 acres, corn, 58.54 acres; grain sorghum, 20 acres; and soybeans, 68.76 acres.

The limiting resource for this combination is labor. Only Dc. 2 period has slack labor.

The land resource has slack of 290.87 acres, therefore, it has no shadow price. This means that additional acres of land would be worth nothing because they would not be used.

The shadow prices for labor are: Ap. 1 - Ma. 1, 73.84; Ma. 2, 87.54; Jn. 2, 8.47; Jl. 1 - Au. 2, 3.67; Sp. 2, 134.08; and Oc. 1, 139.65. As in the four plow case, spring labor has a relatively high shadow price. The higher shadow price for labor in four plow case shows the value of larger equipment and not the efficiency of labor. The very high shadow price for Sp. 2 labor and Oc. 1 labor has the same meaning as the four plow MFWD case.

The shadow prices for the crop resource rows are: wheat, 63.15; corn, 111.00; grain sorghum, 79.10; and soybeans, 95.05.

Model Results vs. Northeast Kansas

The run that best represents the average in 1974 is the four-plow equipment and average field workdays. The majority of the land is used for spring crops. Because spring labor is the limiting factor,

wheat is included to use the remaining acres. Most farms (243 out of 260) in northeast Kansas for 1974 had an average wheat acreage of 87 acres. The four-plow equipment and average field workdays combination included approximately 91 acres.

The model results show the spring crop acreage should be divided approximately equally between corn and soybeans. For average field workdays, the model does not include grain sorghum production. Grain sorghum is grown extensively in northeast Kansas, however, and the reason for excluding it in the model is explored below.

Yields for northeast Kansas for 1974 are taken from "Farm Facts 1974-75" to obtain the average yield by county for grain sorghum and soybeans. (5) The following object values are obtained:

TABLE 4.4

COMPARISON OF GRAIN SORGHUM AND SOYBEANS IN 1974

COUNTY	GRAIN SORGHUM	SOYBEANS
Atchison	\$45.10	\$35.20
Brown	47.58	32.70
Doniphan	73.23	51.20
Jackson	2.58	21.20*
Jefferson	29.13	27.20
Leavenworth	15.40	34.70*
Marchall	-12.28	-3.30**
Nemaha	-2.38	-1.20**
Pottawatomie	18.55	24.70**
Riley	34.53	50.20**

* Soybeans are more profitable than grain sorghum where these counties have a relatively large acreage of soybeans and a small acreage of grain sorghum.

**Soybeans are more profitable than grain sorghum where these counties have a relatively small acreage of soybeans and large acreage of grain sorghum.

The soybeans in northeast Kansas are grown on fertile bottom land while grain sorghum is grown on upland as well as bottom land. The objective values for corn, soybeans and grain sorghum in the model, are based on yields reported for these crops in northeast Kansas. As a result, the values used are based on heterogeneous farmland. The model developed, however, has only one land constraint implying homogeneity of land quality. Consequently, profits from grain sorghum are probably low as compared to corn or soybeans and the model developed is biased toward corn and soybeans.

Both three and four-plow equipment use all 522 acres when average field workdays are used. With four-plow equipment over 650 hours of labor are not used whereas with three-plow about 450 hours of labor are idle. Since three plow equipment requires more labor per acre, less idle labor is expected.

The crop acreage distribution with three-plow equipment is expected to be different from that when four-plow equipment is used. Since spring planted crops are more profitable per acre than wheat, spring crops are planted on as many acres as time allows. The three-plow equipment prepares and plants less spring crops than four-plow equipment since the number of field workdays is the same for both cases. The results from 'Run 3' and 'Run 4' show this does occur. In both cases all available labor is used for the periods April 1 - June 15 when spring crop preparation and planting occurs. The remaining acres are then used for wheat planted in fall. Because more land is available for planting in the fall with the three-plow case, the three-plow equipment will plant more wheat than the four-plow equipment.

Minimum Field Workdays vs. Average Field Workdays

The results with minimum field workdays show fewer acres planted than average field workdays. In approximately 15 percent of the years, there are less than 564 hours available for field work, whereas for the average years there are 1752 hours. With four-plow equipment 1094.39 hours are used which is slightly more than half the hours available in an average year, but about twice the amount available in a very wet year. Consequently, field workdays is a very limiting resource in wet years. The combination of crops is also affected. As expected, land is first allocated to spring crops as they are more profitable than wheat. Land not used for spring crops is then planted to wheat until time limits acreage planted.

'Run 2' results show that all available time in spring, summer and fall is used as expected. The wet year reduces field work completed in the spring more than in the fall, consequently a greater portion of the acres are planted to wheat.

The result of using half the available acres when field workdays are reduced by one half is the result of the property of linearity in linear programming. Farmers would probably utilize a much larger portion of their available land, by cutting back on time for preparing and cultivating. This would enable them to spend less time per acre and thus utilize more land with the time available but with lower per acre returns. Linear programming can be adapted to consider these factors, however, it would result in a much more complex and lengthy programming process. The effect of the assumption of linearity is that runs using minimum field workdays are probably underestimating land use.

Run 1, where minimum field workdays and three-plow equipment is used, has the same interpretation as Run 2. Using three-plow equipment, less land is used but results in about the same crop mix as with four-plow equipment.

Numerous other combinations of field workdays, land, labor and equipment are possible. While testing this model several other runs were made to determine what effect adding more land, labor and equipment would have on crop mix and size of farm. The results of these runs can be found in Table A1.

Determining Trading Three for Four-Plow Equipment

Another problem analyzed with the model is what size farm justifies trading three-plow equipment for four plow. It is assumed that the present operation has one man available with three-plow equipment and average field workdays. An activity allowing a trade of three-plow for four-plow activity is added to the matrix. The objective row value is the difference in annual machinery costs between three and four-plow equipment. The resource values for this activity include a set of positive values for the three-plow equipment which cancels out all the time available to use three-plow equipment, and a set of negative values for the four-plow equipment which supplies a set of four-plow equipment.

Linear programming has the property of infinite divisibility of units, thus it is necessary to force one unit activity of the trading activity. This is done by adding an 'E' row for the trading activities. A value of 1 is placed in this row in the trade activity and a 1 is

entered in the RHS for this row. To determine whether trading is profitable, two runs are required: one run must be made with the trading activity included; the other made with the trading activity excluded. The object values are then compared; the one with the highest value is the most profitable. Therefore, when the object value for the run including the trading activity becomes greater than the run without the trading activity, it becomes profitable to trade three-plow for four-plow equipment. The results obtained from this model for trading are as follows:

1. For average field workdays it becomes profitable to trade three for four-plow equipment when the size of farm exceeds 395 acres.
2. For minimum field workdays it becomes profitable to trade three for four-plow equipment when the size of farm exceeds 215 acres.

The crop mix and object values of these runs may be found in Table 4.5.

TABLE 4.5

DETERMINATION OF TRADING MACHINERY

FIELD WORKDAYS	TRADE 3 FOR 4-PL	FARM SIZE	OBJECT VALUE	WHEAT ACRES	CORN ACRES	GRAIN SORGHUM ACRES	SOYBEAN ACRES
AVERAGE	NO	395	39015.82	41.69	175.61		177.70
AVERAGE	YES	395	38965.75		218.18		176.82
AVERAGE	NO	400	39331.57	46.69	175.61		177.70
AVERAGE	YES	400	39441.00		218.18		181.82
MINIMUM	NO	220	17551.48	82.76	58.54	9.95	68.76
MINIMUM	YES	220	17497.45	64.76	72.73		82.52
MINIMUM	NO	225	17612.38	82.76	58.54	14.95	68.76
MINIMUM	YES	225	17734.80	69.76	72.73		82.52

CHAPTER V

SUMMARY AND CONCLUSIONS

The objective of this study was to develop and test a linear programming model to aid in selecting simultaneously the optimal size of equipment, combination of crops and tillage practices. The selections are based on the field workdays available for northeast Kansas, optimal planting dates for each crop, and capacity of machinery determined by their widths, speed and efficiency.

Findings

The results obtained from the model show that one man with four plow equipment can farm approximately 700 acres with the average number of field workdays. With three plow equipment and the average number of field workdays one man can farm approximately 625 acres. Results show in years with the average number of field workdays all tillage and planting can be done with three or four plow equipment. However, in years which field workdays are limited, machinery is used to full capacity. When the number of field workdays are approximately equal to that expected in less than 15% of the years, neither three or four-plow equipment is large enough to complete all the tillage and planting operations on the average size farm for northeast Kansas.

Results show that spring crops are more profitable than wheat, thus spring crops are planted until limited by the number of field workdays. Remaining acres are then planted to wheat. This results in growing crops on over 80 percent of a 500-acre farm in an average year.

Trading three for four-plow equipment is profitable when crop acres exceed 395 with average number of field workdays. Trading becomes profitable when crop acres exceed 215 acres with minimum number of field workdays. Added income with larger equipment available during a wet year probably affects the higher cost of having larger than necessary size during an average year. Results show that the expected strategy should be:

1. Farm size smaller than 248 acres but larger than 231 acres requires a four-plow equipment capacity to complete field work in all years.
2. When farm size increases above 215 acres, it pays to trade three for four-plow equipment.

Possibilities of Future Studies

More and better data is needed about the timeliness of planting and harvesting crops.

Land resources should be separated to represent various qualities of land in use. If acres of bottom land and upland are used with objective values for each crop and land quality, a better selection of crop mix would be possible.

The number of fixed workdays for November and December used as estimates for the model were based on the assumption that as few or fewer workdays are available in November and December as in October. This was justified from information that less rainfall occurs in November and December than in October. With cooler temperatures in November and December more time is required for the soil surface to dry.

Adding alternative machinery sizes and the possibility of mixing machinery sizes are needed to make this model applicable.

Price studies could also be of interest. By changing the objective values for each crop, the effect of price changes on crop mix can be studied relatively easily.

New labor and machinery coefficients for years when workdays are a limiting factor could be developed to study the effect wet years have on crop mix and land use.

Studies to determine the economic impact of buying additional tractors and other equipment with either part-time or full-time labor would seem to be of interest to farmers also.

REFERENCE

1. Agrawal, R.C. and Heady, Earl o., Operations Research Methods for A Agricultural Decisions, 1st ed. Ames, Iowa; The Iowa State University Press, 1972.
2. Annual Report, Cornbelt Experiment Field, Pawhattan, Kansas, "Date of Planting Corn Trials" 1958-61 and 1963-72.
3. Annual Report, Cornbelt Experiment Field, Pawhattan, Kansas. Sloan, Robert F. "Effect of Planting on Soybean Performance", Kansas State University, 1973.
4. Baumol, William J., Economic Theory and Operations Analysis, 3rd ed. Englewood Cliffs, N.J.; Prentice-Hall, Inc. 1972.
5. Benke, Raymond R. and Winterboer, Ronald, Linear Programming Applications to Agriculture, 1st ed. Ames, Iowa; The Iowa State University Press, 1973.
6. Brink, Lars, Bruce A. McCarl and D. Howard Doster, "Methods and Procedures in the Purdue Crop Budget (Model B-9); An Administrators Guide", Dept. of Agricultural Economics Purdue University.
7. Buller, Orlan; Langemeier, Larry; Kasper, John and Stone, Loyd. "Field Workdays in Kansas", Manhattan, Kansas Agricultural Experiment Station, Kansas State University. Bulletin 596, February, 1976.
8. Figurski, Leo, "Costs of Producing Soybeans in Kansas", Manhattan, Kansas: Kansas Cooperative Extension Service, Farm Management Guide MF-382 (November, 1975).
9. Figurski, Leo, "Dryland Corn Costs and Returns", Manhattan, Kansas: Kansas Cooperative Extension Service, Farm Management Guide MF-262 (November, 1975).
10. Figurski, Leo and McReynolds, Kenneth L., "Continuous Cropped Winter Wheat", Manhattan, Kansas: Kansas Cooperative Extension Service, Farm Management Guide MF-261 (November, 1975).
11. Figurski, Leo and McReynolds, Kenneth L., "Grain Sorghum Costs and Returns", Manhattan, Kansas: Kansas Cooperative Extension Service, Farm Management Guide, MF-271 (November 1975).
12. Figurski, Leo and Shrack, Mark D. "Determining Field Capacity of Farm Machinery", Manhattan, Kansas: Kansas Cooperative Extension Service, Farm Management Guide MF-256 (September, 1973).
13. Heyne, E.G., F.W. Smith, J.A. Hobbs, F.C. Strickler, L.E. Anderson and H.D. Wilkins, "Growing Wheat in Kansas", Agricultural Experiment Station, Kansas State University Bulletin 463, (January 1964).
14. Hunt, D., "A Fortran Program for Selecting Farm Equipment", Agricultural Engineering, The Journal of the American Society of Agricultural Engineers, St. Joseph, Michigan, Vol. 48 No. 6, June, 1967.

REFERENCE

15. Kasper, John L., "Use of Soil Moisture Budget System to Estimate Field Workdays for Riley County, Kansas With Implications for Machinery Sizes", Unpublished Master's Thesis, Kansas State University, 1975.
16. Langemeier, Larry N., Orlan H. Buller and John L. Kasper, "Labor Requirements For Eastern Kansas Crops", Agricultural Experiment Station, Kansas State University, Bulletin 587 (June 1975).
17. Mathematical Programming System 1360, 1st ed., International Business Machines Corporation, 1967.
18. McCarl, Bruce A., W.V. Chandler, D.H. Doster, and P.R. Robbins, "Experience With Mass Audience Linear Programming For Farm Planning", Department of Agricultural Economics, Purdue University.
19. McCarl, Bruce and Falck, Juerene, Documentation Model B-9, West Lafayette, Indiana: Department of Agricultural Economics, Purdue University, Station Bulletin No. 98, September, 1975.
20. Parker, Leonard C; Hackler, R Frank; Dickson, William M. and DeLano, Fredrick D., "Farm Management Summary and Analysis Report", Association No. 4, Kansas 1974. Kansas State University, Department of Economics, Cooperative Extension Service.
21. Smeidler, Neal F., "Optimization of Farm Equipment Selection", Unpublished Master's Thesis, Kansas State University, (1973).
22. Strickler, F.C. and A.W. Pauli, "Yield and Yield Components of Grain Sorghum as Influenced by Date of Planting", Agricultural Experiment Station, Kansas State University, Technical Bulletin 730, (August 1963).
23. USDA Statistical Reporting Service, Crop Reporting Board, Agricultural Prices, Washington, D.C. April 30, 1976 Annual Summary 1974, January 30, 1976.

OTHER MATERIALS CONSULTED

State of Kansas, Department of Agriculture, Statistical Division, Kansas Crop and Livestock Reporting Service. Planting, Development and Harvest of Major Kansas Crops. Topeka, Kansas: (Wilbert H. Walter and John L. Wilson, February, 1963.)

Planting Crops in Kansas. Manhattan, Kansas: Kansas Cooperative Extension Service (May, 1970).

Hunt, D., Farm Power and Machinery Management, Iowa State University Press, Ames, Iowa, (4th Ed.), 1974.

APPENDIX

TABLE A1
MODEL RESULTS

FIELD WORKDAYS	TILLABLE ACRES	ACRES USED	OBJECT VALUE	WHEAT ACRES	CORN ACRES	GRAIN SORGHUM ACRES	SOYBEAN ACRES	NUMBER OF TRACTORS	HIRE FULL- TIME LABOR	HIRE PART- TIME LABOR	SIZE OF EQUIP- MENT
MINIMUM	522	231.13	17681.40	83.83	58.54	20.00	68.76	1	NO	NO	3-PL
MINIMUM	522	231.13	17681.40	83.83	58.54	20.00	68.76	1	NO	YES	3-PL
MINIMUM	522	348.57	24258.52	165.52			183.05	2	NO	YES	3-PL
MINIMUM	522	284.49	21508.26	114.87	72.73	14.37	82.52	1	NO	NO	4-PL
MINIMUM	522	285.50	21555.99	106.25	72.73	24.00	82.52	1	NO	YES	4-PL
MINIMUM	522	388.11	28519.00	200.00	145.45		42.66	2	NO	YES	4-PL
AVERAGE	522	522.00	47035.87	168.69	175.61		177.70	1	NO	NO	3-PL
AVERAGE	1500	627.46	51472.79	256.03			371.43	1	NO	NO	3-PL
AVERAGE	1500	652.51	54769.23	299.20	175.61		177.70	1	NO	YES	3-PL
AVERAGE	1500	1254.92	97041.59	512.06			742.86	2	NO	YES	3-PL
AVERAGE	1500	1305.51	102531.77	581.25	351.22	17.64	355.40	2	YES	YES	3-PL
AVERAGE	522	522.00	50196.99	90.88	218.18		212.94	1	NO	NO	4-PL
AVERAGE	1500	744.80	63595.69	309.28	167.29		268.23	1	NO	NO	4-PL
AVERAGE	1500	804.86	67477.91	373.74	218.18		212.94	1	NO	YES	4-PL
AVERAGE	1500	1489.60	120790.38	618.56	334.58		536.45	2	NO	YES	4-PL
AVERAGE	1500	1500.00	122297.42	637.76	436.36		425.87	2	YES	YES	4-PL

TABLE A2
EXPLANATION OF MATRIX COLUMN AND ROW CODES

ROW CODES	INTERPRETATION
OBJECT	Income Objective
LAND	Land Resource in acres
LAB-AP.1	Labor resource for half month periods; in hours.
⋮	
LAB-DC.2	
PLOW-W	Plowed wheat acres
PREP-W	Prepared wheat acres
PP13-PTW	Links prepared wheat activities in respective
PP4-PTW	periods to wheat planting activities
PT14-HVW	Links wheat planting activities in periods 1-4 to wheat harvesting activities
PREP-C	Prepared corn acres
PP12-PTC	Links corn preparing activities in respective
PP3-PTC	periods to corn planting activities
PP4-PTC	
PT14-CTC	Links corn planting activities in respective
PT5-CTC	periods to corn cultivating activities
PT1-HVC	Links corn planting activities in respective
PT2-HVC	periods to corn harvesting activities
PT3-HVC	
PT4-HVC	
PT5-HVC	
PREP-GS	Prepared grain sorghum acres
PP13-PTG	Links grain sorghum preparing activities in respec-
PP4-PTGS	tive periods to grain sorghum planting activities
PP5-PTGS	
PP6-PTGS	
PT12-CTG	Links grain sorghum planting activities in respec-
PT3-CTGS	tive periods to grain sorghum cultivating activities
PT4-CTGS	

TABLE A2 (continued)

ROW CODES	INTERPRETATION
PT1-HVGS PT2-HVGS PT3-HVGS PT4-HVGS	Links grain sorghum planting activities in respective periods to grain sorghum harvesting activities
PREP-SB	Prepared soybean acres
PP12-PTS PP3-PTSB PP4-PTSB PP5-PTSB PP6-PTSB	Links soybean preparing activities in respective periods to soybean planting activities
PT1-CTSB PT2-CTSB PT3-CTSB PT4-CTSB PT5G-CTS	Links soybean planting activities in respective periods to soybean cultivating activities
PT12-HVSB PT3-HVSB PT4-HVSB PT5-HVSB PT6-HVSB	Links soybean planting activities in respective periods to soybean harvesting activities
TRACT3PL TRACT4PL	Three-plow tractor purchase row Four-plow tractor purchase row
TRT3AP.1(TRT4AP.1) : : TRT3DC.2(TRT4DC.2)	Three-plow(four-plow) tractor resource in hours for half-month periods
PLOW-3(PLOW-4) ANHYD3PS(ANHYD4PS) ANHYD3PF(ANHYD4PF) DISC-3PS(DISC-4PS) DISC-3PF(DISC-4PF) FD-CULT3 (FD-CULT4)	Three (four) bottom plow resource in hours Anhydrous applicator, three-plow size (four-plow size) for use on spring planted crops Anhydrous applicator, three-plow size (four-plow size) for use on fall planted crops Disc resource row, three-plow (four-plow) size, in hours for spring planted crops Disc resource row, three-plow (four-plow) size, in hours for fall planted crops Field cultivator resource in hours, three-plow (four-plow) size

TABLE A2 (continued)

ROW CODES	INTERPRETATION
PLANTER3(PLANTER4)	Planter resource in hours, three-plow (four-plow) size.
DRILL-3P(DRILL-4P)	Drill resource in hours, three-plow (four-plow) size
ROT-HOE3(ROT-HOE4)	Rotary hoe resource in hours, three-plow (four-plow) size
CULT-3P(CULT-4P)	Cultivator resource in hours, three-plow (four-plow) size
COMB-3PS(COMB-4PS)	Combine resource in hours for summer harvested crops, three-plow (four-plow) size
COMB-3PF(COMB-4PF)	Combine resource in hours for fall harvested crops, three-plow (four-plow) size

COLUMN CODES	INTERPRETATION
RHS	Right hand side, fixed resources

Crop Activities

WHEAT	These activities provide the income objective per acre and land requirement. They also link the crop activity to the tillage activity
CORN	
GRAIN SORGHUM	
SOYBEANS	

Tillage Activities

Because there are numerous tillage activities, a list of all tillage codes is not presented. It is sufficient to present a breakdown of the code by presenting a few examples from which the interpretation of the remaining codes can be deduced.

PLOW-W31	The first four letters of the code refer to the tillage operation: PLOW, for plowing activities; PREP, for preparing activities; PLNT, for planting activities; CULT, for cultivating activities; and HARV, for harvesting activities. The next <u>letter(s)</u> of the code refers to the crop for which the tillage activity is performed: W, for Wheat; C, for corn; G or GS, for grain sorghum; and S or SB, for soybeans. The first number refers to equipment size: 3, for three-plow equipment; and 4, for four-plow equipment. The second number refers to the activity period in which the activity for that crop is performed.
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TABLE A2 (continued)

COLUMN CODES	INTERPRETATION
	When a third number is present, there exists an overlap in the time periods for the code's tillage activity and a tillage activity which must be completed prior to the code activity. For example, wheat planting and wheat preparing periods overlap, but wheat planting on a given acre must not occur before wheat preparing on that acre. Rows were used to accomplish the linkage in the proper manner. The third number corresponds to the row which links the two activities.
PLNTW322	This code has the following interpretation: This is a wheat planting activity using three-plow equipment. Planting occurs in the second wheat planting period. Preparation occurs in the periods referred to in the second row linking wheat preparing activities to wheat planting activities, which is PP4-PTW. Thus, the acres being planted were prepared in the fourth wheat preparing period.
<u>Miscellaneous Activities</u>	
BLBAP.1	Hiring part-time labor
:	
BLBDC.2	
BUYFTLB	Hiring full-time labor
BY3PLTRT	Buying a three-plow tractor
BY4PLTRT	Buying a four-plow tractor
BY3PCOMB	Buying a three-plow size combine
BY4PCOMB	Buying a four-plow size combine
TD3PL-4P	Trading three-plow equipment for four-plow equipment

TABLE A3
LISTING OF TILLAGE ACTIVITIES BY PERIOD AND DATES

TILLAGE ACTIVITIES	DATE
Wheat Plowing Periods	
1	July 1 - 15
2	July 16 - 31
3	Aug. 1 - 15
Wheat Preparing Periods	
1	Aug. 1 - 15
2	Aug. 16 - 31
3	Sept. 1 - 15
4	Sept. 16 - 30
Wheat Planting Periods	
1	Sept. 1 - 15
2	Sept. 16 - 30
3	Oct. 1 - 15
4	Oct. 16 - 31
Wheat Harvesting Periods	
1	June 16 - 30
2	July 1 - 15
3	July 16 - 31
Corn Preparing Periods	
1	Apr. 1 - 15
2	Apr. 16 - 30
3	May 1 - 15
4	May 16 - 31
Corn Planting Periods	
1	Apr. 1 - 15
2	Apr. 16 - 30
3	May 1 - 15
4	May 16 - 31
5	June 1 - 15

TABLE A3 (continued)

TILLAGE ACTIVITIES	DATE
Corn Cultivating Periods	
1	June 15 - 30
2	July 1 - 15
3	July 16 - 31
4	Aug. 1 - 15
Corn Harvesting Periods	
1	Sept. 15 - 30
2	Oct. 1 - 15
3	Oct. 16 - 31
4	Nov. 1 - 15
5	Nov. 16 - 30
6	Dec. 1 - 15
7	Dec. 16 - 31
Grain Sorghum Preparing Periods	
1	Apr. 1 - 15
2	Apr. 16 - 30
3	May 1 - 15
4	May 16 - 31
5	June 1 - 15
6	June 16 - 30
Grain Sorghum Planting Periods	
1	May 1 - 15
2	May 16 - 31
3	June 1 - 15
4	June 16 - 30
Grain Sorghum Cultivating Periods	
1	June 15 - 30
2	July 1 - 15
3	July 16 - 31
4	Aug. 1 - 15

TABLE A3 (continued)

TILLAGE ACTIVITIES	DATE
Grain Sorghum Harvesting Periods	
1	Sept. 15 - 30
2	Oct. 1 - 15
3	Oct. 16 - 31
4	Nov. 1 - 15
5	Nov. 16 - 30
6	Dec. 1 - 15
7	Dec. 16 - 31
Soybean Preparing Periods	
1	Apr. 1 - 15
2	Apr. 16 - 30
3	May 1 - 15
4	May 16 - 31
5	June 1 - 15
Soybean Planting Periods	
1	Apr. 16 - 30
2	May 1 - 15
3	May 16 - 31
4	June 1 - 15
5	June 16 - 30
6	July 1 - 15
Soybean Cultivating Periods	
1	June 1 - 15
2	June 16 - 30
3	July 1 - 15
4	July 16 - 31
5	Aug. 1 - 15
Soybean Harvesting Periods	
1	Sept. 16 - 30
2	Oct. 1 - 15
3	Oct. 16 - 31
4	Nov. 1 - 15
5	Nov. 16 - 30
6	Dec. 1 - 15
7	Dec. 16 - 31

TABLE A4

L-P MATRIX FOR NORTHEAST KANSAS*

- * The L-P Matrix used for this model is listed in row and column form on the following 59 pages. It contains all activities developed for northeast Kansas when average number of field workdays are available.

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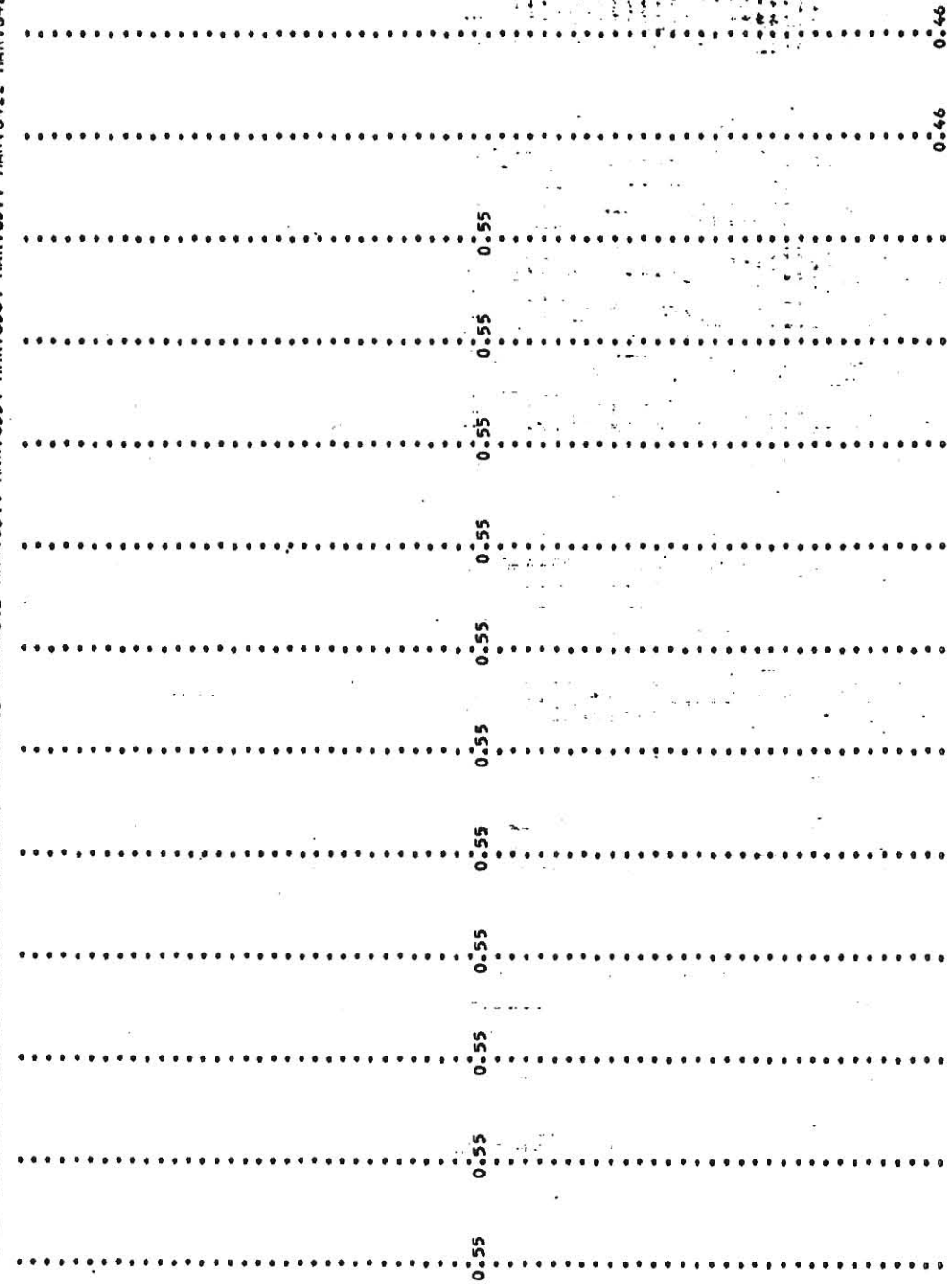
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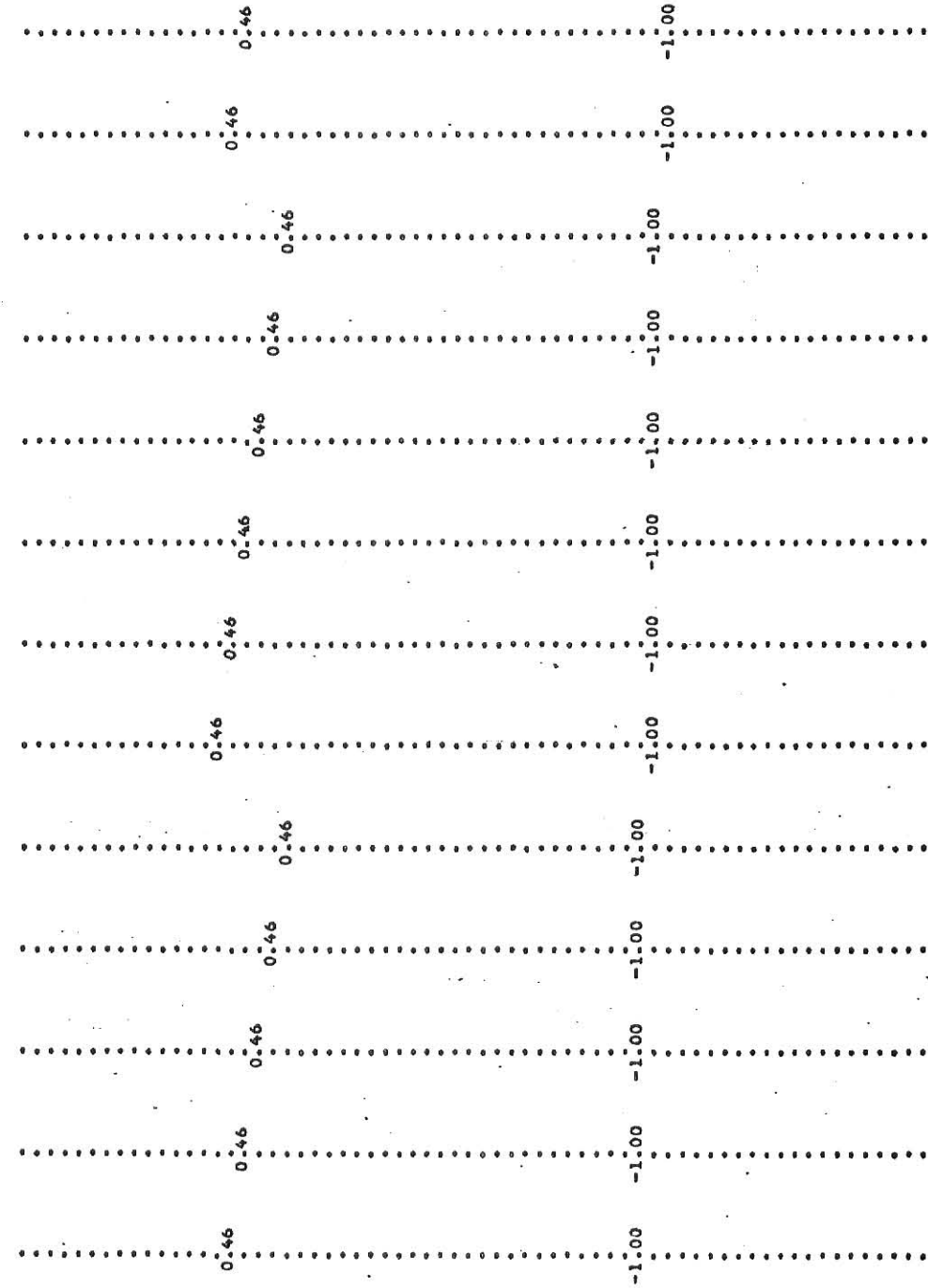
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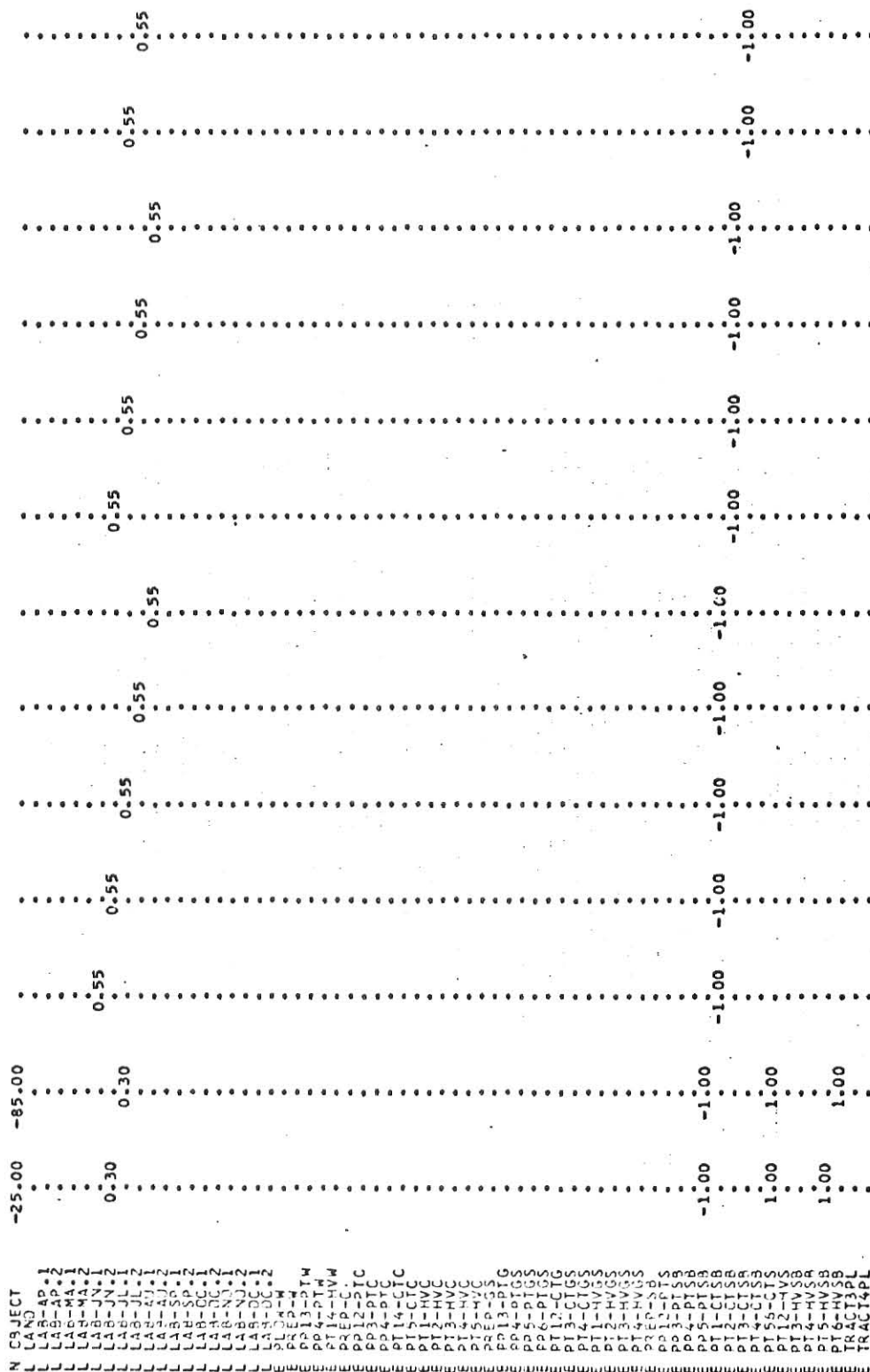
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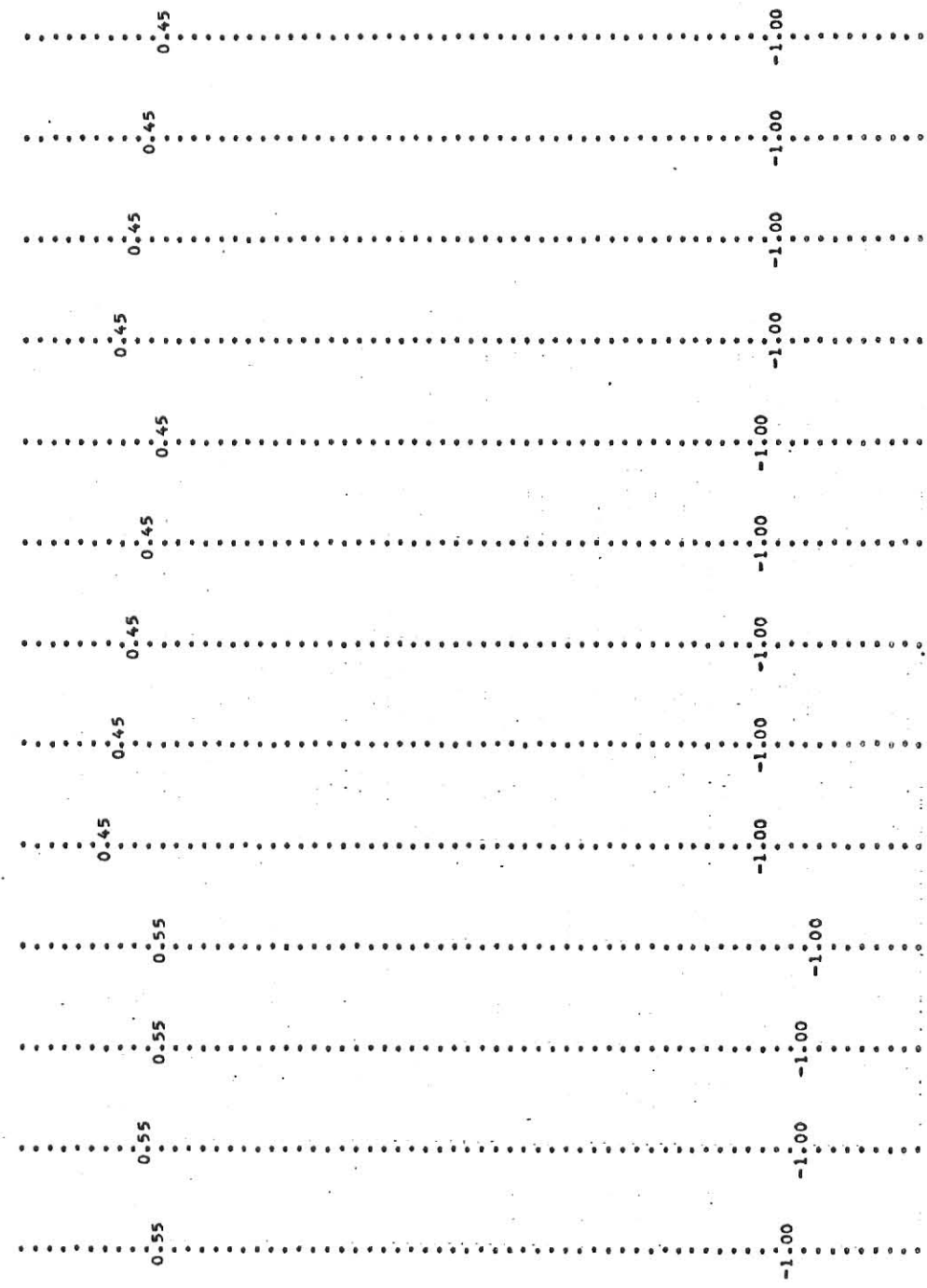


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FARM MACHINERY SELECTION:
A LINEAR PROGRAMMING MODEL

by

THOMAS F. TICE

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Tice, Thomas F. M.S., Kansas State University, December, 1976. Farm Machinery Selection, A Linear Programming Model. Major Professor: Orlan H. Buller.

The object of this study is to develop and test a linear programming model for northeast Kansas cash grain farms, that simultaneously select the most profitable size of machinery, combination of crops and tillage practices. Choice of machinery, crops and tillage activities is based on the amount of land, labor and field workdays available.

The average size of farm for northeast Kansas is estimated using data from the Farm Management Summary and Analysis Report for Association No. 4. The average size is approximately 500 tillable acres.

The field workday is estimated using a Soil Moisture Budget System which uses meteorological data including rainfall and evaporation measurements. Estimates of the average number and a minimum number of expected field workdays is used to test the model.

The model selects from either three or four-plow equipment.

Costs and yield data from the Kansas Cooperative Extension Service is used to determine the income for the four major cash grain crops grown in northeast Kansas.

Model results are compared with the average size farm in northeast to test the model. The field workdays in 1974 approximates the number of field workdays available in an average year so the average field workday model result is compared to results obtained on farms in 1974.

The model chooses approximately the same proportion of spring and fall planted crops as was planted by farmers in northeast Kansas. The

model chooses corn and soybeans in approximately equal proportions for spring planting. Farmers in northeast Kansas grow a considerable quantity of grain sorghum which is not reflected by the model results. The difference is attributed to differences in land quality and risk factors which the model did not include.

Trading three for four-plow equipment is briefly examined. It is found that farmers will profit by trading when the size of the farm exceeds 215 acres with few workdays available or when acreage exceeds 395 acres with average workdays available.